DRAFT

Duwamish/Diagonal CSO/SD
Cleanup Study Report

Elliott Bay/Duwamish Restoration Program

Prepared for:
Elliott Bay/Duwamish Restoration Program Panel

Prepared by:
King County Department of Natural Resources
Anchor Environmental, LLC
EcoChem, Inc.

December 2001

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF COMMON ABBREVIATIONS, ACRONYMS, AND TERMS

<MDL	Less than Method Detection Limit
<RDL	Detected below the Reporting Detection Limit
AET	Apparent Effects Threshold when bioassays show toxicity
Armored Shoreline	Rock covered shoreline
Aroclor	Industrial name for Polychlorinated Biphenyl (PCB)
AWQC	Ambient Water Quality Criteria
BNA	Base/Neutral/Acid, part of extractable organic chemistry analysis
CAD	Confined Aquatic Disposal
CEQ	Council of Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, Liability Act
CFR	Code of Federal Regulations
Channel Area	Part of study area located in dredged navigation channel
City	City of Seattle
cm	centimeter
cm/s	centimeter per second
cm/yr	centimeter per year
COCs	Chemicals of Concern relative to sediment cleanup needs
CSL	Cleanup Screening Levels criteria establishes minor adverse effects level
2CSL	Concentrations that are two times the CSL values
CSO	Combined Sewer Overflow
CWA	Clean Water Act
cy	cubic yards
DEA	David Evans and Associates
Diagonal SD/CSO	Large City storm water drain plus CSO east of Kellogg Island
Diagonal Ave. S. Treatment Plant	Historic sewage treatment plant that discharged east of Kellogg Is.
Diagonal Drainage Basin	On east side of Duwamish River adjacent to Diagonal SD
DNR	Department of Natural Resources
DU/DI	Duwamish CSO and Diagonal SD/CSO study area
Duwamish Avenue South SD	Small City storm water drain east of Kellogg Island
Duwamish CSO	King County emergency CSO outfall east of Kellogg Island
Duwamish Siphon	Sewage pipes under the Duwamish River near Kellogg Island
DW	Dry Weight, but also used for Dangerous Waste disposal category
DWU	Drainage and Wastewater Utility for City of Seattle
E	Data qualifier for estimated value
EA	Environmental Assessment
EBDRP	Elliott Bay/Duwamish Restoration Program
Ecology	Washington State Department of Ecology
EDMI	Electronic Distance Measuring System
EFH	Essential Fish Habitat
EHW	Extremely Hazardous Waste is a designation that determines disposal options
EPA data	Sediment chemistry for 300 Duwamish River stations sampled in 1998
EPA	U.S. Environmental Protection Agency
E Shaped Pier	Offshore pier of piling clusters previously used by Lafarge Cement

Flashpoint	Measure of ignitability in dangerous waste determination
FONSI	Finding of No Significant Impact
ft	feet
G	Data qualifier for low SRM recovery/low surrogate recovery/low MS recovery
GPS	Global Positioning System
GRE	Growth rate endpoint for Neanthes bioassay test
Hanford Drainage Basin	In Rainer Valley, but connects to Diagonal SD/CSO
HH	Halogenated hydrocarbons are considered persistent constituents
Hot Spot	Increased chemical concentration in a small geographic area
HPAH	High Molecular Weight Polycyclic Aromatic Hydrocarbons
HQ	Hazard Quotient is ratio of exposure dose to the no adverse effect dose
J	Data qualifier for tentatively detected
KC	King County
KCEL	King County Environmental Laboratory
KCDMS	King County Department of Metropolitan Services
KCDNR	King County Department of Natural Resources
L	Data qualifier for high SRM, matrix spike, or surrogate recovery
LAET	Lowest Apparent Effects Threshold
2LAET	Second Lowest Apparent Effects Threshold
Low Salinity Sediments	Pore water values between 0.5 and 25 parts per thousand
LPAH	Low Molecular Weight Polycyclic Aromatic Hydrocarbons
m	meters
Marine Sediments	Pore water salinity greater than 25 parts per thousand
Mass Balance Model	Recontamination based on discharge inputs and outputs
MCUL	Minimum Cleanup Level
MDL	Method Detection Limit
METSED	Modified SEDCAM model used by Metro/King County staff
Metro	Municipality of Metropolitan Seattle
mg/Kg OCN	milligrams/Kilogram Organic Carbon Normalized units in SMS
MGY	Million Gallons per Year
MGD	Million Gallons per Day
MLLW	Mean Lower Low Water
MS	Matrix Spike
MUDS	Multi-User Disposal Site
MTCA	Model Toxics Control Act
NAD83	North American Datum for 1983 denotes state plane coordinate grid
NCD	Nearshore Confined Disposal
NEPA	National Environmental Policy Act
NOAA	National Oceanic and Atmospheric Administration
North Inshore Area	Part of study area nearest to Duwamish and Diagonal outfalls
NPL	National Priorities List of contaminated sites leads to Superfund designation
NRDA	Natural Resource Damage Assessment
OCN	Organic Carbon Normalized value used for certain SMS organic chemicals
PAH	Polycyclic Aromatic Hydrocarbons
PCB	Polychlorinated Biphenyl
PEIS	Programmatic Environmental Impact Statement
PIE	Pacific International Engineering, PLLC

Phase 1 Sampling	August 1994, surface grabs, bioassays, cores
Phase 1.5 Sampling	November 1995, added surface grabs
Phase 2 Sampling	May, June, July, Sept, 1996, cores, surface grabs, bioassays
Port	Port of Seattle
ppt	parts per thousand
PSAMP	Puget Sound Ambient Monitoring Program conducted by State
PSD	Particle Size Distribution of sediment samples
PSDDA	Puget Sound Dredge Disposal Analysis
PSEP	Puget Sound Estuary Program
PSWQA	Puget Sound Water Quality Authority
PVC	Polyvinyl chloride
QA	Quality Assurance
QA1 Review	Quality Assurance Review
QA/QC	Quality Assurance/Quality Control relative to data generation
QC	Quality Control
Qual	Data Qualifier Codes
RCRA	Resource Conservation and Recovery Act
RCW	Revised Code of Washington
RDL	Reporting detection limit
RSD	Relative Percent Difference for replicate samples
s	second
SAP	Sampling and Analysis Plan
SD	Storm water Drain that discharges separated storm water
SD/CSO	An outfall for both a SD and CSO, with storm water the biggest volume
SEDCAM	Model discussed by Ecology for calculating recontamination potential
SEPA	State Environmental Policy Act (for Washington State)
SMS	Sediment Management Standards prepared by Ecology for Washington State
SMS Bioassay	10- day Amphipod, Echinoderm Embryo, and 20- day Neanthes
SMURF	Sediment Multi-User Remediation Facility
South Inshore Area	Part of study area south of Duwamish and Diagonal outfalls
SQS	Sediment Quality Standards criteria values establishes no adverse effects level
SRTWG	Sediment Remediation Technical Working Group for EBDRP
SRM	Standard Reference Materials
Study Area	Duwamish River offshore from Duwamish/Diagonal outfalls
TCLP	Toxicity Characteristics Leaching Procedure
TOC	Total Organic Carbon
TPH	Total Petroleum Hydrocarbons
TSCA	Toxic Substances Control Act
U	Data qualifier for undetected value in sample
USACE	United States Army Corps of Engineers
USC	Unites States Code
WAC	Washington Administrative Code
WDFW	Washington State Department of Fish and Wildlife
WDOE	Washington State Department of Ecology
WDNR	Washington State Department of Natural Resources

Executive Summary

The Elliott Bay/Duwamish Restoration Program (EBDRP) was established to implement the requirements of a 1991 Consent Decree defining the terms of a settlement for natural resource damages. The goals of the EBDRP include remediation of contaminated sediment associated with Metro (previously Municipality of Metropolitan Seattle and now King County Department of Natural Resources [KCDNR]) and City of Seattle (City) combined sewer overflows (CSOs) and storm drains (SDs).

This Cleanup Study Report addresses contaminated sediment associated with the KCDNR Duwamish CSO outfall and the nearby City Diagonal Way SD/CSO outfall (Duwamish/Diagonal outfalls), both of which are either historic or current discharges to the Duwamish Waterway in Seattle, Washington. A small primary treatment plant rated at about 8 MGD was first operated by the City (1940-1961) and then Metro (1962-1969) and discharged upstream of these outfalls for about 30 years until it was closed in 1969.

Site assessment activities included identification of contaminants of concern, delineation of the extent and magnitude of sediment contamination around the outfalls, as well as evaluations of CSO-reduction measures and watershed source controls within the study area. As part of this effort, KCDNR performed three rounds of sediment sampling and analysis between August 1994 and September 1996. Recontamination modeling based on these data was performed during this period by KCDNR and during mid-1999 by WEST Consultants. Information presented in this Report is used to refine the final cleanup area and assist in the selection and design of sediment cleanup alternatives.

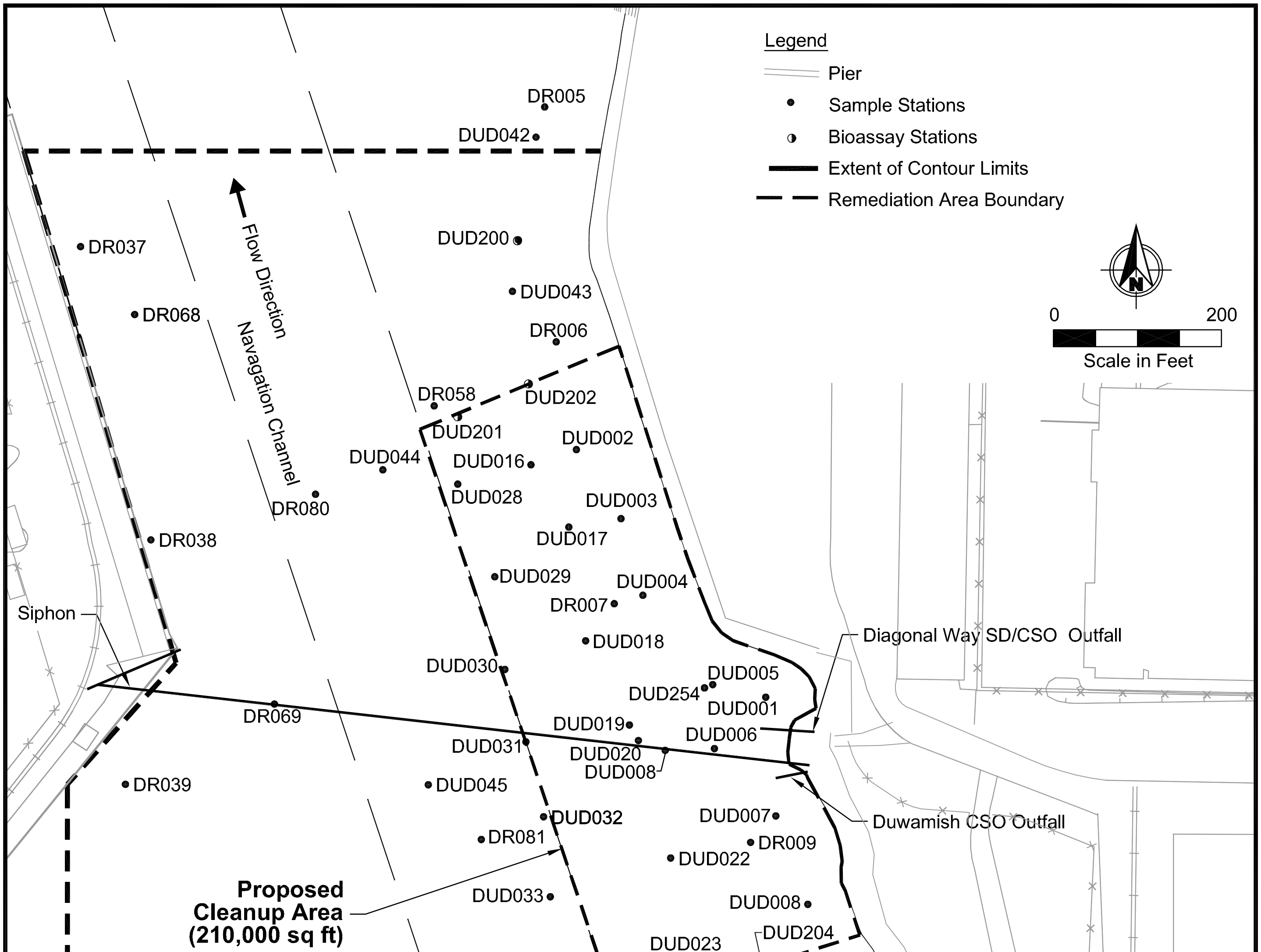
Major conclusions of this Cleanup Study Report are:

- CSO discharges from the Duwamish CSO outfall are controlled to less than one overflow event per year. None are known to have occurred since 1989. CSO discharges from the Diagonal Way SD/CSO outfall historically exceeded 300 million gallons per year (MGY) and continue to average over twenty events per year with a total annual CSO discharge volume estimated to be about 65 MGY.
- Stormwater currently discharges through the Diagonal Way SD/CSO outfall from both the Diagonal and Hanford Drainage Basins, with a combined drainage area of 1,583 acres. This outfall contributes a significant quantity of water to the Duwamish River during storm events, with an estimated discharge volume of 1,230 MGY.
- Watershed source control efforts being implemented or planned in the Diagonal/Hanford Drainage Basin by City Drainage and Wastewater Utility staff include storm drain sediment removal, business inspections, public education, response to citizen complaints, and tracking the source of a recurrent oil sheen.
- The major chemicals of concern found in sediment in the study area near the Duwamish/Diagonal outfalls are PCBs, mercury, bis (2-ethylhexyl) phthalate, and butyl

benzyl phthalate. A phthalate “hot spot” is present directly in front of the Diagonal SD/CSO outfall, but there is a band of elevated phthalate surface concentrations that extends upstream and downstream. Bioassay testing at stations located 350 to 500 feet from the outfall showed no toxicity to three bioassay tests even though these stations had elevated levels of phthalates.

- A rectangular cleanup boundary was established for the site based on the following conditions: 1) setting the western cleanup boundary to the physical limits imposed by the navigation channel; 2) setting the northern cleanup boundary to stations exhibiting no exceedances of sediment bioassay criteria; 3) setting the southern cleanup boundary to stations exhibiting no exceedances or limited exceedances (less than CSL) of sediment bioassay criteria; and 4) setting the eastern cleanup boundary to the shoreline. The encompassed area is estimated at 4.8 acres (approximately 210,000 square feet, **Figure ES-1**).
- Depth of sediment contamination is variable. Sediment core data indicate that concentrations exceeding sediment criteria extend to depths of 3 to 9 feet, depending on the particular chemical and core location. In addition, some chemicals (e.g., PCBs) show increasing concentrations with depth near the outfalls.
- Recontamination modeling performed by KCDNR in 1997 indicated that recontamination by bis (2-ethylhexyl) phthalate from stormwater could occur, but this would be limited to the area near the outfalls.
- A mass balance model by WEST Consultants (1999) suggests that, even with nearly total source control of the phthalate discharges, there would potentially be SQS exceedances produced solely by the background concentrations of phthalates in suspended particulate matter in the study area.
- The data from King County and EPA studies indicate a localized area of PCBs in the general Duwamish/Diagonal study area. This localized area suggests using PCBs as the primary chemical of concern rather than phthalates. PCBs are primary chemicals of concern for the Duwamish River sediment because these chlorinated compounds bioaccumulate in organisms and represent both human health and ecological risks. Removal of PCB "hot spots" in sediment is a priority for regulatory agencies and the tribes.
- Current discharge pipes are not a significant source of PCBs.
- The greatest threat of PCB recontamination in the study area is from potential dredging activities that disturb and mobilize existing PCB-contaminated sediments. Efforts should be made to minimize recontamination potential by coordinating when and how dredging projects are carried out in this section of the river.
- The 4.8-acre area in front of the Duwamish/ Diagonal outfalls was selected as the proposed remediation site for the EBDRP program and does not include a chemical “hot spot” located upstream near the former Diagonal Treatment plant outfall. That area will be addressed under future Superfund activities in the lower Duwamish River.

- Site constraints affecting cleanup feasibility were enumerated, and a screening-level natural recovery/ recontamination model was run for PCBs. The model indicated that natural recovery would not occur in an acceptable time frame (10 years), dredging could release contaminated sediments, and that cleanup would accelerate recovery to below the SQS within a 5 to 10 year period.
- Potential remedial technologies were screened and appropriate technologies were combined into remedial alternatives. The alternatives were then evaluated and compared, with a dredging and capping alternative that results in no change to existing elevations selected as the preferred alternative.
- The preferred alternative removes 42,500 cubic yards (cy) of sediment with a clamshell dredge and sends it to an off-site facility; the exact facility is not yet determined. Following dredging, the remediation site will be capped with clean backfill material (42,500 cy) to isolate remaining sediment contamination from the environment. The final design will utilize USACE and EPA guidance documents for designing isolation caps.
- Compliance monitoring would be performed following the completion of the remedial action to ensure the continued effectiveness of the cleanup remedy.
- The preferred alternative was preliminarily identified as the option that uses permanent solutions to the maximum extent practicable. Public comments received could modify the cleanup analysis and/or preferred alternative presented herein.



00-086-01

DWD044-01

12/18/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure ES-1
	Final Focus Area	

1.0 INTRODUCTION

This Cleanup Study Report characterizes the spatial extent and significance of chemical contamination detected in sediment near the King County Duwamish CSO and the City of Seattle Diagonal Way CSO/SD outfall (Duwamish/Diagonal outfalls), located in the Duwamish River. Data from the sediment chemistry characterization of the site are in **Appendix A**. Information presented in this Report has been used to finalize a cleanup area and assist in the selection and design of sediment cleanup alternatives. This Draft Cleanup Study Report is issued consistent with Washington State Sediment Management Standards (SMS), Chapter 173-204 Washington Administrative Code (WAC).

1.1 PROJECT OVERVIEW

To implement the requirements of a 1991 Consent Decree defining the terms of a settlement of alleged natural resource damages, the Elliott Bay/Duwamish Restoration Program (EBDRP) was established. Program oversight is provided by the EBDRP Panel, which is composed of federal, state, and tribal natural resource trustees, the Municipality of Metropolitan Seattle (Metro, which subsequently became part of King County government and is now the King County Department of Natural Resources [KCDNR]), and the City of Seattle (City). The goals of the EBDRP include remediation of contaminated sediment associated with KCDNR and City CSOs and SDs, and restoration of habitat in Elliott Bay and the Duwamish River.

In 1992, a Sediment Remediation Technical Working Group (SRTWG) was established by the EBDRP Panel to address contaminated sediment issues. The SRTWG identified 24 potential sediment remediation sites associated with KCDNR and City CSOs and SDs. These sites were evaluated against several criteria, which included extent of contamination, degree of source control near sites, and public input, as reported in the Final Concept Document (EBDRP 1994a). Ultimately, the SRTWG selected three sites (the Duwamish Pump Station CSO and Diagonal Way CSO/SD; the Norfolk CSO; and the Seattle Waterfront) for further investigation. This Cleanup Study Report addresses only the Duwamish Pump Station CSO and the Diagonal Way CSO/SD outfalls, which were combined into one site due to their proximity (i.e., the Duwamish/Diagonal outfalls).

In 1994, the Duwamish/Diagonal Cleanup Study Plan was prepared by KCDNR (then Metro) on behalf of the EBDRP Panel. The five documents that comprise the Plan are the Workplan (EBDRP 1994b), the Sampling and Analysis Plan (EBDRP 1994c), the Phase 2 Sampling and Analysis Plan (EBDRP 1996a), the Health and Safety Plan (EBDRP 1994d), and the Public Participation Plan (EBDRP 1994e). These plans provide the framework for the Duwamish/Diagonal sediment cleanup study.

The 1994 Workplan identified nine chemicals or classes of chemicals of potential concern based on six preliminary sediment samples collected in 1992 near the outfalls (**Appendix B**, Pre-Phase 1 Data). The chemicals of concern exceeding Sediment

Management Standards (SMS) sediment quality criteria were mercury, silver, zinc, chlorinated benzenes, phthalate acid esters, polychlorinated biphenyls (PCBs), high molecular weight polycyclic aromatic hydrocarbons (HPAHs), benzoic acid, and tributyltin.

KCDNR implemented field collection activities, described in the Sampling and Analysis Plan, between August 1994 and September 1996. The primary goal was to determine the extent of sediment contamination around the Duwamish/Diagonal outfalls based on comparison to SMS criteria. Sediment chemistry data collected by U.S. Environmental Protection Agency (EPA) in 1998 for a National Priority List evaluation were also used to define areas exceeding SMS for four specific chemicals: PCBs, mercury and two phthalate compounds. Sediment recontamination modeling, to assess whether sediment cleanup could lead to long-term SMS compliance, was undertaken as part of this assessment and ultimately considered two different methodologies. The results of these efforts are presented in this Report.

1.2 REPORT ORGANIZATION

This Report is organized into nine main sections:

- **Chapter 1** provides a project overview.
- **Chapter 2** describes the environmental setting and natural resources of the project area.
- **Chapter 3** presents a source control evaluation, including identification of contaminant sources, completed CSO reductions, and potential for sediment recontamination based on modeling results.
- **Chapter 4** describes the data collection efforts and chemical results associated with the cleanup study including sampling and testing methods, quality assurance review results, sediment chemistry results, sediment bioassay results, and waste disposal characteristics.
- **Chapter 5** presents the data interpretation including comparison to SMS criteria, evaluation of concentration gradients, comparison to upgradient concentrations, identification of chemicals of concern, potential for contaminant migration and fate, and determination of the area to be evaluated further.
- **Chapter 6** outlines the applicable laws and regulations pertaining to cleanup actions at the site.
- **Chapter 7** identifies the range of known available technologies and process options capable of achieving remediation of the contaminated sediments at the Duwamish/Diagonal site.

- **Chapter 8** assembles, screens, and develops alternatives from the technology types and process options retained from Chapter 7.
- **Chapter 9** evaluates the alternatives against eight criteria presented in WAC 173-204-560(4)(f)(iii) and selects the preferred alternative.

2.0 SITE DESCRIPTION

2.1. PROJECT LOCATION

The Duwamish/Diagonal Study Area (Study Area) is located at approximately river kilometer (km) 3 in the lower portion of the Duwamish River, within the south industrial section of Seattle, Washington (**Figure 2-1**). The Duwamish/Diagonal outfalls are located on the east side of the Duwamish River, upstream of Harbor Island and immediately downstream of Kellogg Island.

The Diagonal outfall is located south of Port of Seattle's Terminal 106 at the South Oregon Street unimproved right-of-way (**Figure 2-2**). This outfall has a large concrete discharge structure for the 144-inch diameter pipe, which is totally exposed at -3 feet Mean Lower Low Water (MLLW). The 36-inch diameter Duwamish outfall is submerged and discharges in the waterway approximately 30 meters (m) (100 feet) south of the Diagonal outfall.

The Study Area includes the offshore area surrounding the two outfalls. In addition, two outfalls located within 1,000 feet upstream (the former City sewage treatment plant outfall and the Diagonal Avenue South SD outfall) are included in the Study Area to evaluate upstream conditions.

2.2. ADJACENT LAND USE AND PROPERTY DESCRIPTIONS

Land use in the vicinity of the Study Area is primarily industrial (**Figure 2-2**). A railroad yard is located approximately 0.7 km east of the Duwamish/Diagonal outfalls. The Port of Seattle's Terminal 106 container facility is located north (downstream) of the outfalls, and the Port of Seattle's Terminal 108 container facility is located just south of the outfalls. Only a portion of Terminal 108 is paved and the eastern part is used for container storage. Seattle City Light has an easement for the power transmission lines located along the South Oregon Street right-of-way, and these lines cross the Duwamish River just north of the outfalls. From 1989 to 1999 the LaFarge Corporation operated a cement plant southeast of the Duwamish/Diagonal outfalls. A large Washington State Liquor Control Board warehouse is located approximately 90 m northeast of the outfalls.

Shoreline in the vicinity of the Study Area has been designated as Urban Industrial (special designation for water-dependent use), Conservancy Preservation, and Conservancy Recreation (conditional and special use for habitat enhancement; PTI 1993). Shoreline uses include cargo transfer, industrial warehousing, barge repair, habitat restoration, and tribal and recreational fishing. Submerged lands in the Duwamish Waterway are owned by the City and the Port of Seattle (**Figure 2-3**).

2.3. SHORELINE FEATURES AND BATHYMETRY

The intertidal area in the vicinity of the outfalls is generally riprapped, except for a small pocket-beach located just north of the Diagonal outfall. Below the riprapped shoreline, the lower beach is sand with cobble. Directly in front of the Diagonal outfall, a flocculent mud delta has developed.

Bathymetry surveys were conducted in the Study Area in 1992, 1994, 1996, and 1997. Dredging to create the original shipping channel produced the steep slopes that define the riverbanks in this stretch of the waterway. Water depth in the Study Area ranges from about +13 feet above MLLW at maximum high tide to a dredged depth of -30 feet below MLLW in the channel (**Figure 2-4**). An intertidal delta extends into the river in front of the Diagonal SD/CSO outfall. Bathymetry data show that downstream of the outfalls, the river bottom slopes evenly from the shore toward the middle of the river.

Upstream of the outfalls, the bottom slopes steeply from the shore to a depth of 16 to 18 feet and then flattens out for approximately 200 feet before sloping steeply again toward the middle of the river. This large area of flat bottom topography upstream of the outfalls was created in 1977 when Chiyoda Corporation dredged the area to create a loading dock facility (**Figure 2-5**, Historic Activities). As part of this project, the shoreline between the Diagonal SD/CSO outfall and the outfall for the former Diagonal treatment plant was excavated and moved east about 30 meters (100 feet). The contaminated dredged material was placed upland on the old treatment plant site. A 1976 aerial photo (C-3, **Appendix C**) shows the shoreline before modification and clearly shows the two settling ponds that were built at the north end of the treatment plant property to contain PCB contaminated sediments dredged from Slip 1 in 1976. A 1977 aerial photo (C-4, **Appendix C**) shows the shoreline modified and the entire treatment plant property leveled leaving no sign of the two settling ponds or the old sludge lagoons. Permit applications indicate the excavated sediments were to be used as fill along the new shoreline and other parts of the old treatment plant site. Chiyoda's proposal for a shore-based dock was denied during permit application and the E-shaped pier near the former Diagonal Avenue treatment plant outfall was installed offshore (**Figure 2-4**).

During installation of the Diagonal SD/CSO outfall, the Duwamish CSO outfall, and the Duwamish siphon sewer lines in 1965-1967, sediment was dredged and backfilled near the outfalls and across the waterway. The siphon pipes (42-inch and 21-inch diameter pipes) were buried in a trench that was dredged across the river bottom. Detailed bathymetry contours in the Study Area (**Figure 2-6**) show that inshore of the east channel line there is a depression approximately 150 feet wide near the siphon line, suggesting that the area was not backfilled to its original depth. As part of the same contract to install the siphon, the City installed the 12-foot diameter Diagonal storm drainpipe and the large rectangular outfall structure in 1965-1967. **Table 2.1** provides a listing of historic property ownership and construction activities in the Study Area. In the navigation channel, the top of the siphon is at an elevation of about 46.5 feet below MLLW, while the channel depth is specified to be -30 feet MLLW.

Table 2.1 HISTORY OF PROPERTY OWNERSHIP AND CONSTRUCTION ACTIVITIES NEAR SITE

Year(s)	Details
1940-1961	City of Seattle builds and operates Diagonal Avenue Sewage Treatment Plant with outfall along east bank of the Duwamish River and capacity to treat about 8.0 million gallons per day (MGD)
1962-1969	Metro takes over operation of Diagonal Avenue Sewage Treatment Plant performing extensive remodeling initially to provide better operational flexibility and efficiency until the plant is closed in 1969.
1966-1997	Metro builds twin buried siphon lines (21 and 42 inch) across the river which are called

Year(s)	Details
	the Duwamish Siphon and on the east shore includes a submerged CSO overflow pipe called the Duwamish CSO (Siphon plans dated 6/65 with as built stamp dated 5/31/67). The Duwamish Siphon transports flow from West Seattle to the Duwamish Pump Station being constructed on the east side of the river.
1966-1967	City of Seattle completes installation of Diagonal storm drainpipe along north side of former treatment plant property and includes the large rectangular Duwamish SD/CSO outfall structure on the east river bank. Prior to pipe installation, a slough existed along the north side of the property and received the untreated sewage discharge from a small sewer system located to the northeast. The Diagonal SD/CSO outfall and the submerged Duwamish CSO outfall are about 100 feet apart and were constructed under the same contract.
1967	Port of Seattle dredges on west side of river along the face of Terminal 105, which starts at the west side of the Duwamish Siphon crossing and extends downstream about 700 feet (150,444 cubic yards was maximum quantity permitted).
1968	Corps of Engineers dredges easterly one half of navigation channel in area just upstream of Duwamish Siphon and extending upstream to past the north end of Kellogg Island (between USACE stations 51 - 60 with 7,000 cubic yards maximum quantity permitted).
1968	Metro completes construction of Elliott Bay Interceptor (EBI) along east side of Duwamish River to transport sewage flow to West Point Treatment Plant that started operation in1964.
1969	Metro begins operation of the newly constructed Duwamish Pump Station, which receives flow from the south through the EBI and from the west through the Duwamish Siphon. The pump station lifts these flows for gravity transport north in the EBI.
1969	Metro closes Diagonal Avenue Treatment Plant and all flows are directed to the EBI.
1970	Port of Seattle makes a major change in the east riverbank north of the Duwamish SD/CSO when they install a long rock bulkhead in the river and backfill the site to create about 900 linear feet of new river front property that is now the Terminal 106 property.
1974	Documented PCB spill of about 255 gallons of Aroclor 1242 into Slip 1 when an electric transformer was dropped and broken on the north pier of Slip 1 on 9/13/74. Initial dredging activities in Slip 1 recovers an estimated 80 gallons of the spilled PCBs.
Mid 1970's	Chiyoda Corporation buys the old Diagonal Avenue Treatment Plant site and plans to build a shore based loading dock facility along the riverbank.
1975	Corps of Engineers negotiates with Chiyoda Corporation to allow PCB contaminated dredged spoils to be placed in 2 pits excavated in the old sludge ponds located on the north end of the former treatment plant property.
1976	Corps of Engineers conducts second dredging for PCBs at northwest corner of Slip 1 using hydraulic dredging to settling ponds on Chiyoda property. They estimate that the dredging removed another 170 gallons of the 255-gallon spill of Aroclor 1242 resulting in a total recovery of 98%.

Year(s)	Details
1977	Chiyoda Corporation dredges a berthing area making a major change in the east shoreline in the area between the Diagonal Siphon and the former Diagonal Ave. treatment plant outfall. The shoreline is moved east about 100 feet and the near shore area deepened, which likely removes historic contaminated bottom sediment. The estimated 80,000 cubic yards of dredge material is used to fill the near shore area, the holding ponds, and to level the former treatment plant site. Chiyoda is denied a permit to build a shore based dock facility so the project ends without a dock.
1984	Corps of Engineers dredges shoal of contaminated sediment from channel near the former Diagonal Avenue treatment plant outfall and removes about 1100 cubic yards of contaminated sediment. The disposal for these contaminated sediments involves depositing them in a depression in the bottom of the West Waterway and covering them over to an average depth of about 2 feet with about 4200 cubic yards of clean sand dredged from the upper turning basin.
1985	Port of Seattle purchases former Diagonal Avenue treatment plant property from Chiyoda Corporation and subdivides property into 2 lots. Lot B is located along the river and Lot A is located farther east away from the river. Chevron Corporation purchases Lot A at this time, but they later deed the property back to the Port in 1992.
1989	On Lot B, the Port of Seattle develops Terminal 108 and LaFarge Corporation uses the site for bulk dry cement receiving, storage, and trans-shipment. An offshore pier consisting of piling clusters is installed in the river near the abandon outfall of the former Diagonal Avenue treatment plant.
1989	Port of Seattle constructs a 1.1 acre public shoreline access site at the street end of Diagonal Avenue as mitigation for installing riprap improvements on the shoreline upstream (south) of the abandon outfall of the former Diagonal Avenue treatment plant.
1992	Port of Seattle obtains Lot A from Chevron Corporation and uses all of the property for an expanded container storage facility connected with Terminal 106 to the north.
1994	On January 1,1994, Metro merges with other King County departments and King County assumes ownership of all former Metro sewer collection systems, treatment plants and CSO facilities.
1998	LaFarge Corporation closes the bulk dry cement receiving, storage, and trans-shipment site. Port of Seattle removes all land-based structures including the conveyor system to the pier. The pier remains and the property is currently for lease.

It appears the backfill material used to cover the Siphon pipes in 1966-1967 may have been contaminated with PCBs because core samples collected near the Siphon alignment have elevated PCBs extending down to the deepest core section (6-9 feet). The original source of the PCB contamination in the backfill material is not known. Two potential historic sources of PCBs to this part of the river are the following: 1) a wastewater drainage slough that entered the river about where the

Diagonal SD/CSO outfall was constructed in 1967 and 2) the old treatment plant outfall located upstream (operated from 1940-1969).

2.3.1. Navigation

The lower 9.6-km of the Duwamish River is maintained as a navigable waterway by the U.S. Army Corps of Engineers (USACE). In the Study Area the navigation channel is delineated by straight, parallel lines, generally aligned with the shore. The eastern side of the navigation channel is approximately 250 feet from the east bank of the River in the vicinity of the outfalls. The navigation channel is approximately 60 m (200 feet) wide and about 9 m (30 feet) deep (below MLLW; Weston 1993). According to USACE bathymetry, depths in the navigation channel range from 26 to 35 feet (all depths MLLW). Most of the channel was dredged prior to 1960, but a portion immediately upstream of the site was dredged in 1968 (Tetra Tech 1988). The navigation channel is intended to be maintained at a depth of 30 feet, however, a 50 feet wide and more than 1,200 feet long shoal has developed along the east side of the waterway across from Kellogg Island (**Figure 2-4**). The northernmost portion of the shoal extends approximately to the Duwamish/Diagonal outfalls. Eventually, dredging of this area will be required to maintain the channel.

In 1984, the USACE conducted an emergency dredging action directly off the old treatment plant outfall to remove a shoal that had reduced the navigation channel depth down to -25 feet instead of the required -30 feet depth. The USACE removed one barge load of contaminated sediment to restore the channel depth. Detailed bathymetry from 1994 (**Figure 2-6**) shows "U" shaped contour lines located near the east channel line offshore from the old /Diagonal Ave. S. treatment plant outfall on surveys from 1992 and 1994 indicating that the USACE dredging extended slightly east of the east channel line. The source of this rapidly appearing shoal was not investigated at the time, but the volume of contaminated sediment is too large to be from an accidental barge dump. Close inspection of the detailed contour lines (**Figure 2-6**) shows that the 1977 dredging project created a small ridge of sediment on the upstream side of the old treatment plant outfall. If part of this narrow ridge of contaminated sediment was unstable and slid off into the channel in 1983, it could have produced the type of shoal that the USACE had to remove in 1984.

2.4. WATER RESOURCES

2.4.1. Duwamish River

The Duwamish River begins at the confluence of the Black and Green Rivers at approximately river km 19. The Duwamish/Diagonal Study Area is located at approximately river km 3. The Duwamish River is a salt-wedge estuary, with tides influencing the river over its entire length (Dexter et. al. 1981). The mean tidal range in the lower 7 km of the Duwamish River is approximately 2.3 m. The distance upstream to the toe of the salt wedge (salinity at least 25 parts per thousand) depends on the tidal amplitude and freshwater discharge. At high tide during periods of low flow, the salt wedge has extended upstream to approximately river km 16. Conversely, at low tide during periods of high flow the wedge has extended only to river km 6.4 (Santos and Stoner 1972). Little mixing of the salt wedge and river water occurs except in the lower 6 km when discharge rates are low (Dexter et al. 1981).

The salinity of the upper river water layer increases in the downstream direction, but the salinity of the bottom layer remains fairly constant except at the toe of the salt wedge (Santos and Stoner 1972).

The Duwamish River at the Study Area ranges from partly mixed to well stratified for low to high discharges, respectively. The thickness of the fresh and salt-water layers varies with tides and the river discharge. The salinity at a given depth is generally stable laterally, but can vary with depth between 2 to 28 parts per thousand (ppt) (Santos and Stoner 1972). Salinity in the main channel sediments is closer to marine conditions because of the stability of the salt wedge in the deeper channel.

River flow is regulated upstream on the Green River by the Howard Hansen Dam. The annual average river discharge is 47 cubic meters per second (m^3/sec) and the probable maximum flood is approximately 400 m^3/sec. The annual suspended sediment discharge from the Duwamish River was estimated to be 1,700 metric tons per year, based on daily measurements of suspended sediments in the mid-1960s (Dexter et al. 1981). Recent data collected for the Elliott Bay Waterfront Recontamination Study (EBDRP 1995) and records for the 1943 to 1983 period indicate an average Duwamish River total suspended solids (TSS) load of 7,600 metric tons per year. The lower Duwamish River tends to be a depositional zone with deposition rates estimated to be on the order of 5 cm/year in the Study Area (Harper-Owes 1983). More recent data indicate that the sedimentation rate near Harbor Island is between 1 and 1.5 cm/year (EVS 1996).

In a University of Washington study at the Duwamish/Diagonal Study Area, tidal velocities were measured to assess the likelihood of sediment erosion (Dail 1996). The results of that study are inconclusive. Maximum velocities of 30 centimeters per second (cm/s) were measured at the sampling location, 50 cm above the riverbed. Based on sediment samples at the site, a critical velocity (the velocity at which erosion would begin to occur) of 16 cm/s was estimated. Since observed velocities were higher than this critical velocity, erosional events were expected during the monitoring period. However, field observations did not provide evidence of erosional events. Hence, the results of this study are inconclusive.

2.4.2. Surface Water Drainage and CSOs

The lower reaches of the Duwamish River in the Study Area have been heavily modified by human activity. Surface water drainage patterns in the original watersheds have generally been replaced by public and private drainage systems designed to route water away from commercial, residential, and industrial properties and into either piped drainage systems or the remaining wetlands.

Surface drainage and sewage (from CSOs) can enter the Duwamish River in the vicinity of Study Area from three discharge pipes, however only the first one is a significant source:

- Diagonal Way SD/CSO outfall (144-inch diameter)
- Duwamish CSO outfall (36-inch diameter, no overflows since 1989)
- Diagonal Avenue South SD outfall (18-inch diameter)

The locations of these sources and other relevant features are shown in **Figure 2-2**.

The Diagonal Way SD/CSO outfall is located south of the Port of Seattle's Terminal 106 at the South Oregon Street unimproved street right-of-way. This outfall contributes a significant quantity of water to the river during storm events, estimated at 1,230 million gallons per year (MGY). The 144-inch diameter outfall receives CSO and stormwater flows from both the Diagonal and Hanford drainage basins (**Figure 2-7**). Most City of Seattle and King County CSO points that can discharge into the stormwater system have been controlled by separation and storage to occur less frequently than one overflow event per year. However, recent information has determined that the King County Hanford #1 CSO is not totally controlled, and is estimated to discharge about 65 MGY out of the Diagonal Way SD/CSO outfall (Swarner personal communication 1999). The Diagonal and Hanford drainage basins have a combined drainage area of about 1,583 acres. Due to the industrial and commercial nature of sections of these basins, there is a significant amount of impervious surface area. Stormwater runoff to the system originates from Interstate 5 (I-5) between mile marks 156 and 163, the Central District, the Rainier Valley, the Duwamish industrial area, and residential Beacon Hill (City of Seattle 1996). The Seattle Drainage and Wastewater Utility (DWU) data are included as **Appendix D**. The Diagonal drainage basin is located on the East Side of the Duwamish River adjacent to the outfall. Land use in the basin is predominantly commercial and industrial west of I-5 and residential east of I-5 (City of Seattle 1996). The Hanford drainage basin is located in the Rainier Valley; stormwater flows are transported to the Diagonal outfall via the Hanford tunnel. In addition to runoff from the Diagonal and Hanford Basins, stormwater from Terminal 106 is carried by a Port of Seattle drain to the Diagonal outfall pipe. This Port of Seattle drain previously discharged into a small cove downstream of the Duwamish/Diagonal outfalls. Additional outfall information is included in **Appendix E**.

The Duwamish CSO outfall enters the Duwamish River roughly 30 m (100 feet) south of the Diagonal SD/CSO outfall. Flows that have the potential to discharge from the Duwamish CSO originate on the west side of the Duwamish Waterway from the Delridge Trunk Sewer, the Chelan Avenue Regulator Station, and the East Marginal Way Pump Station. The flow is routed to the West Duwamish Interceptor and then to the siphon forebay. The flow is carried east under the waterway through a siphon of two pipes to the siphon aftbay on the east shore. The flow then travels to the Elliott Bay Interceptor via the Duwamish Pump Station. Outfall pipes are connected at both the siphon forebay and the siphon aftbay structures. The 36-inch diameter Duwamish CSO outfall originates at an overflow structure near the siphon aftbay. Due to the configuration of the Duwamish CSO outfall, overflows are highly unlikely (EBDRP 1994b). The Duwamish CSO outfall is not known to have overflowed during the period from 1989 to the present; no overflows are anticipated in the future except under emergency conditions. Additional outfall information is included in **Appendix E**

The Diagonal Avenue South SD is located 300 m (approximately 1,000 feet) south (upstream) of the Duwamish/Diagonal outfalls. The 18-inch diameter drain is attached to a concrete slab located in the upper intertidal area of the sloping shoreline. The drain receives runoff from a 12-acre drainage basin south of the Duwamish/Diagonal outfall between East Marginal Way and the Duwamish River and to the north of Diagonal Avenue South (Tetra Tech 1988). Most of the drainage area is paved and apparently has been used for storage by the surrounding properties (Tetra Tech 1988). This outfall serves an area comprising less than one percent of the areas served by the Diagonal Way SD/CSO outfall.

2.4.3. Groundwater Drainage

The Duwamish Valley is located in the central Puget Sound lowland physiographic province. The geology of the area is characterized (from depth to surface) as regional bedrock, glacial erosion and deposition, and fluvial deposition by the Duwamish River. Groundwater flow rates and direction in the vicinity of the Study Area are expected to be complex because of the presence of a filled river channel to the east of the existing river channel. Fill depth near the Study Area is generally 3 m to 6 m. The fill is predominantly silt and silty sand. Fine and medium sand with silt lenses underlies the fill (Sweet, Edwards & Associates and Harper-Owes 1985). The Sweet, Edwards & Associates Study reports a typical hydraulic conductivity in the surficial material of 0.01 cm/s and a hydraulic gradient of 0.0037 feet per foot. Using Darcy's Law, with a conservatively large saturated thickness of 15 m in hydraulic communication with the river, the groundwater flow towards the river would be approximately 0.005 m^3/s per km of channel. This flow is very small compared to the riverine and tidal flows and would generally only be of concern if the groundwater were very contaminated. Site-specific groundwater data for a property adjacent to the study area is presented in **Section 3.2.7** and indicates that groundwater in this area would not pose a risk to aquatic receptors in the Waterway.

2.5. ECOLOGICAL RESOURCES

2.5.1. Habitat

As part of the Duwamish/Diagonal Site Assessment, biologists from Pentec Environmental, Inc. performed two visits to the Study Area to observe existing habitat conditions. During the July 29, 1996, site visit, seven transects were established along the eastern shoreline of the Study Area. At each transect, qualitative information was collected for substrate type, community dominants, macroinfauna, and slope and bank height. Field observations are summarized below; detailed memos and transect profiles are included in **Appendix F**.

The entire visible intertidal area downstream of the E-shaped pier is generally riprap constructed in about 1977 during a shoreline excavation to make a berthing area (C-4, **Appendix C**). At mid-to-lower intertidal elevations, the riprap and pilings support a typical epibiota dominated by barnacles (*Balanus glandula*), mussels (*Mytilus trossulus*), and rockweed (*Fucus gardneri*). Large numbers of mussels of reasonable size (30 to 50 mm) may comprise the most probable pathway for contaminant accumulation by a species that could be consumed by humans.

At transect 7 (located halfway between the upstream E-shaped pier and the Duwamish/Diagonal outfalls), the substratum consists of ballast rock from the highwater mark out to 9 feet on the transect. The major portion of the slope is armored with riprap at a slope of 30 degrees. A band of sand and clay was exposed at the water's edge below the toe of the riprap. The hard substratum was covered with seaweeds (extensively with *Fucus;* some *Enteromorpha;* and *Mastocarpus*). Just upstream of the Diagonal/Duwamish outfalls the hardrock substratum community was well established on the rocks, the slope appeared steeper (35 degrees) here and was armored with large riprap.

Directly in front of the Diagonal/Duwamish outfalls, a very soft, flocculent mud delta was present, with a strong hydrogen sulfide/hydrocarbon odor. The sediment appeared anoxic with hydrocarbon seeps present on the surface. No evidence of an infauna community was observed. In association with this project, the City has conducted source control investigations to identify the source(s) of the petroleum discharging from the Diagonal outfall. Seattle Drainage and Wastewater Utility (DWU) source investigation data are included in **Appendix D**.

Just downstream (north) of the Diagonal outfall, a small pocket-beach supports a good infauna with abundant polychaetes and oligiochaetes. Shore crabs (*Hemigrapsus oregonensis*) were common under cobbles on the beach but no clams were found. The beach slope downstream of the pocket-beach consisted of a heavily armored riprap slope of 45 degrees with a *Fucus* dominated community. This long section of armored shoreline was constructed in 1970 as part of the Port of Seattle development of Terminal 106 (C-2, **Appendix C**).

A good opportunity for large-scale habitat enhancement may exist in the area just upstream (south) of the Duwamish outfall. The uplands behind the top of the riprapped shoreline are currently unused and contain an early successional scrub shrub. If this property were available, the shoreline could be cut back substantially, thus adding habitat area in selected intertidal elevations. The middle and lower beach could be resurfaced with a silty sand, and the upper intertidal area planted with a fringe of saltmarsh vegetation.

2.5.2. Fish and Wildlife

The following information has been compiled from various sources and represents fish and wildlife species observed in various portions of the Duwamish estuary. Not all of the species discussed below may actually use the Study Area.

The Duwamish estuary provides nursery habitat for numerous marine fish species and juvenile salmonids. Studies conducted in the lower Duwamish River have identified more than 20 marine and anadromous fish species (Parametrix 1980, Warner and Fritz, 1995). Marine fish species found in abundance include English sole, starry flounder, Pacific staghorn sculpin, shiner perch, and Pacific herring. Juvenile sole species and Pacific staghorn sculpin were found in the estuary over the entire year.

The lower 10 to 13 km of the Duwamish estuary is an important transition zone for juvenile salmonids to acclimate to saltwater (Parametrix 1980). The Duwamish/Diagonal outfalls are located within this transition zone at river km 3 and may provide feeding areas for fish. The Green River (located upstream of the Duwamish) and the lower reaches of its tributaries provide important spawning habitat.

Studies have shown that, of the five Pacific salmon species, chinook salmon are most dependent on estuaries during the early stages of their life cycle (Varanasi et al. 1993). Juvenile Chinook salmon were found to be most abundant near Kellogg Island between April and June (Parametrix 1982), and juvenile chum salmon were most abundant in April and May. Coho salmon have been found in fewer numbers near Kellogg Island and do not appear to use this habitat as extensively as chum and Chinook salmon. The diet of juvenile Chinook salmon was found to consist of copepods, amphipods, insects, annelids, and small fish (Varanasi et al. 1993).

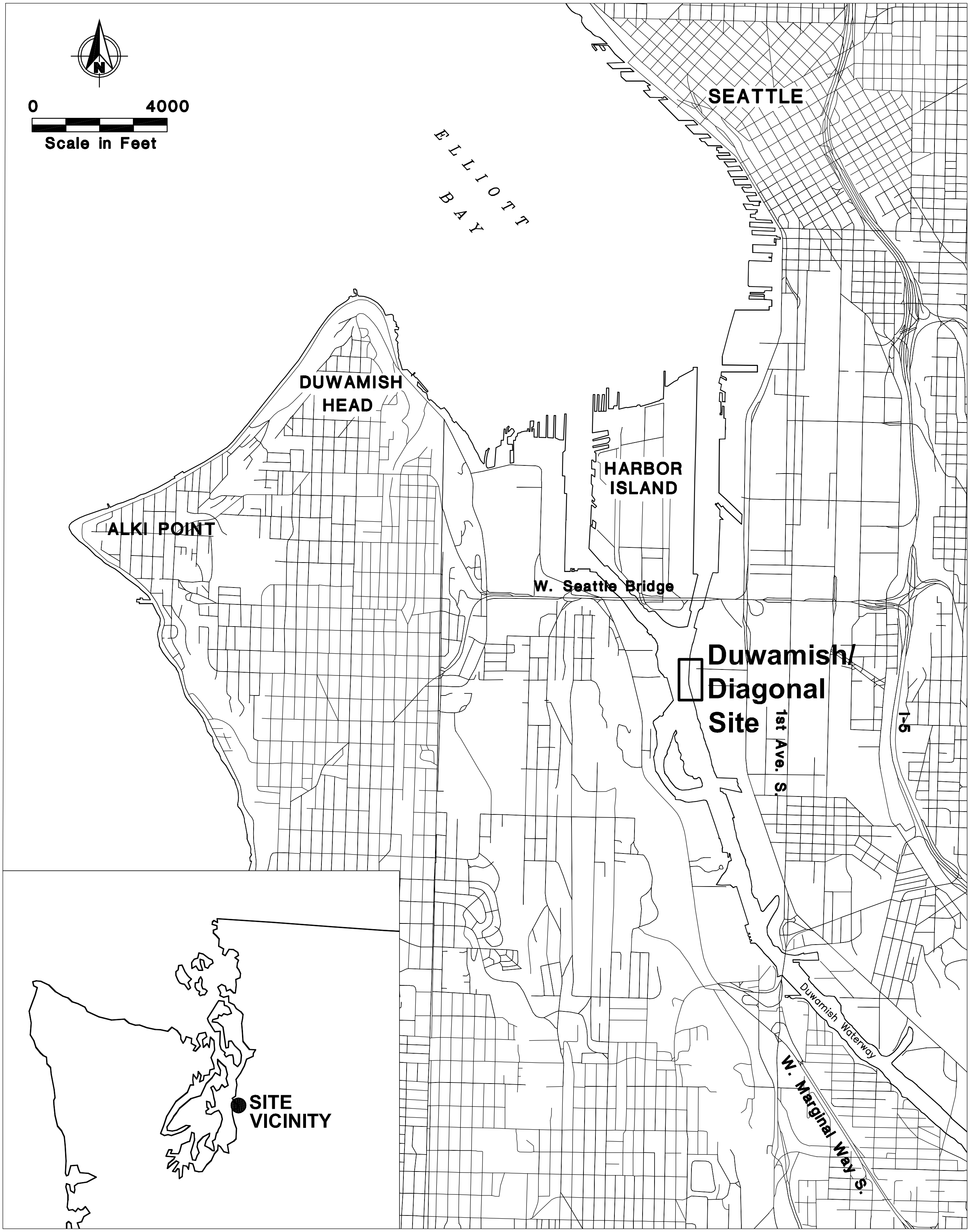
Nine mammal species have been observed in the Duwamish River estuary (Tanner 1991). Aquatic species include the harbor seal, killer whale, Steller sea lion, muskrat, and river otter, while terrestrial species include the Norway rat, raccoon, snowshoe hare, and Townsend vole.

Eighty-four bird species have been observed in the Duwamish River estuary (Tanner 1991). Kellogg Island provides important nesting habitat for birds. Nests observed during surveys conducted in the late 1970s included American goldfinch, California quail, Canada goose, gadwall, killdeer, northern oriole, red-winged blackbird, song sparrow, and spotted sandpiper (Canning et al. 1979).

2.5.3. Beneficial Uses

Salmonids are considered the most commercially and recreationally important fish species using the Duwamish River. Species include chinook, coho, and chum salmon, steelhead and sea-run cutthroat trout, and Dolly Varden char (Parametrix 1980).

The Duwamish River estuary is within the usual and accustomed fishing ground of the Muckelshoot Tribe, which harvests almost exclusively non-resident fish such as salmon (EBDRP 1994b). Tribal fishing occurs with river skiff gill nets (PTI 1993). In addition to the tribal fishery, the Green and Duwamish Rivers sustain a major sport fishery for steelhead and are also popular for salmon (Grette and Salo 1986). The Muckelshoot Tribe and Washington State Department of Fisheries operate hatcheries located on tributaries to the Green River. The Muckelshoot hatchery produces Chinook salmon, chum salmon, and steelhead trout. The state hatchery has primarily produced coho and fall chinook salmon (Grette and Salo 1986).

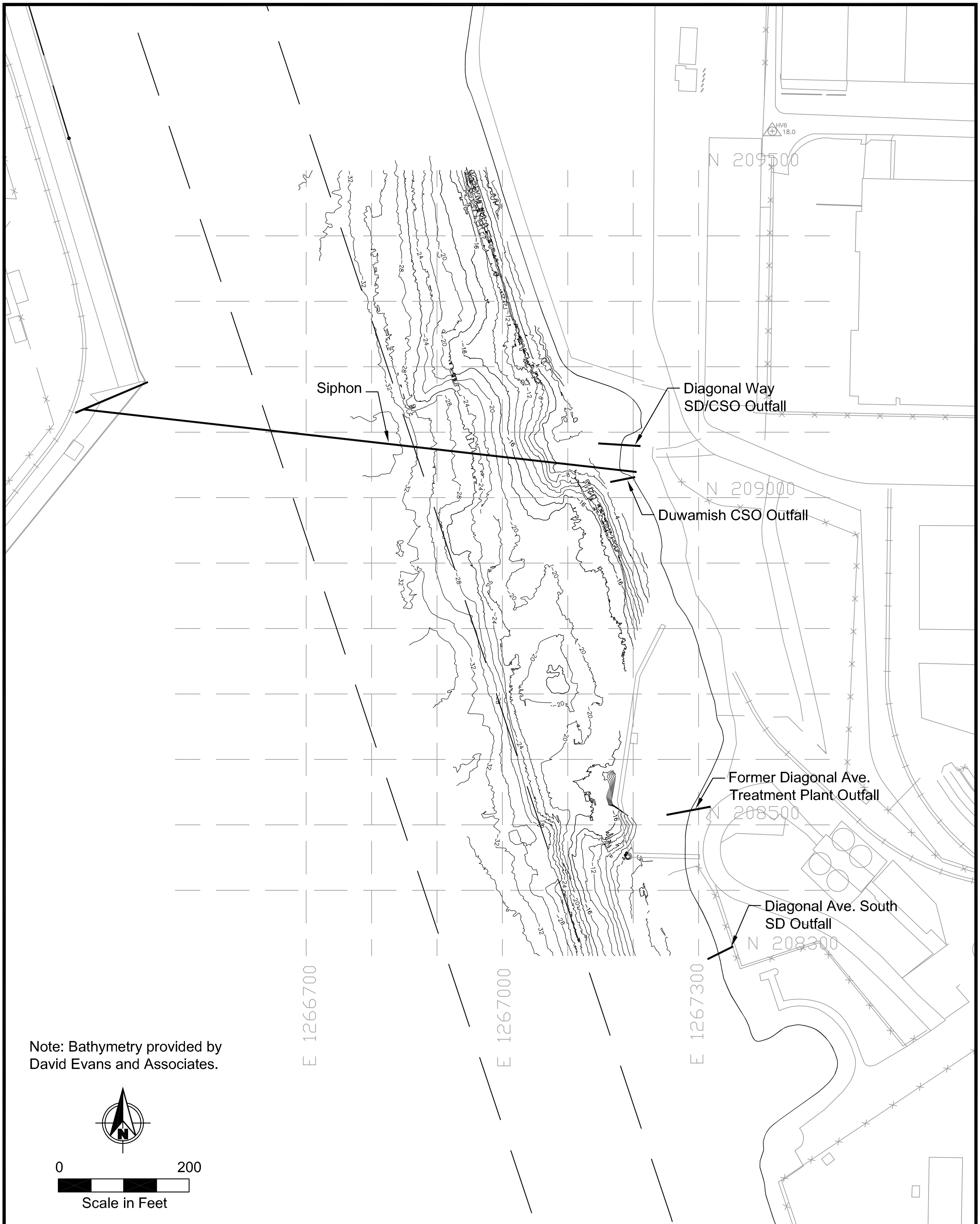


00-086-01

DWD016-01.dwg

12/14/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Duwamish/Diagonal Vicinity Map	Figure 2-1



00-086-01

DWD043-01.dwg

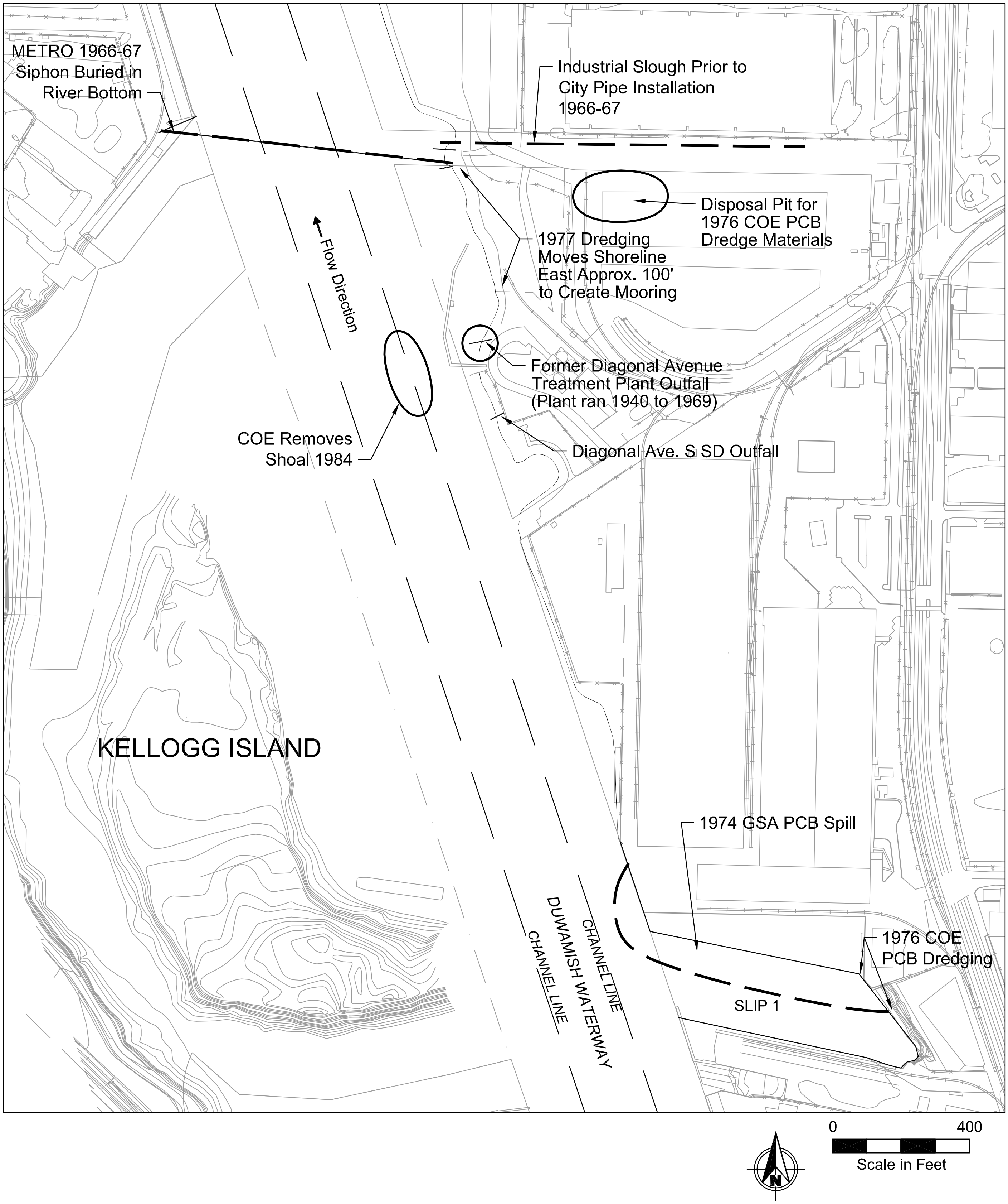
12/20/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Duwamish/Diagonal 1996 Bathymetry

Figure 2-6

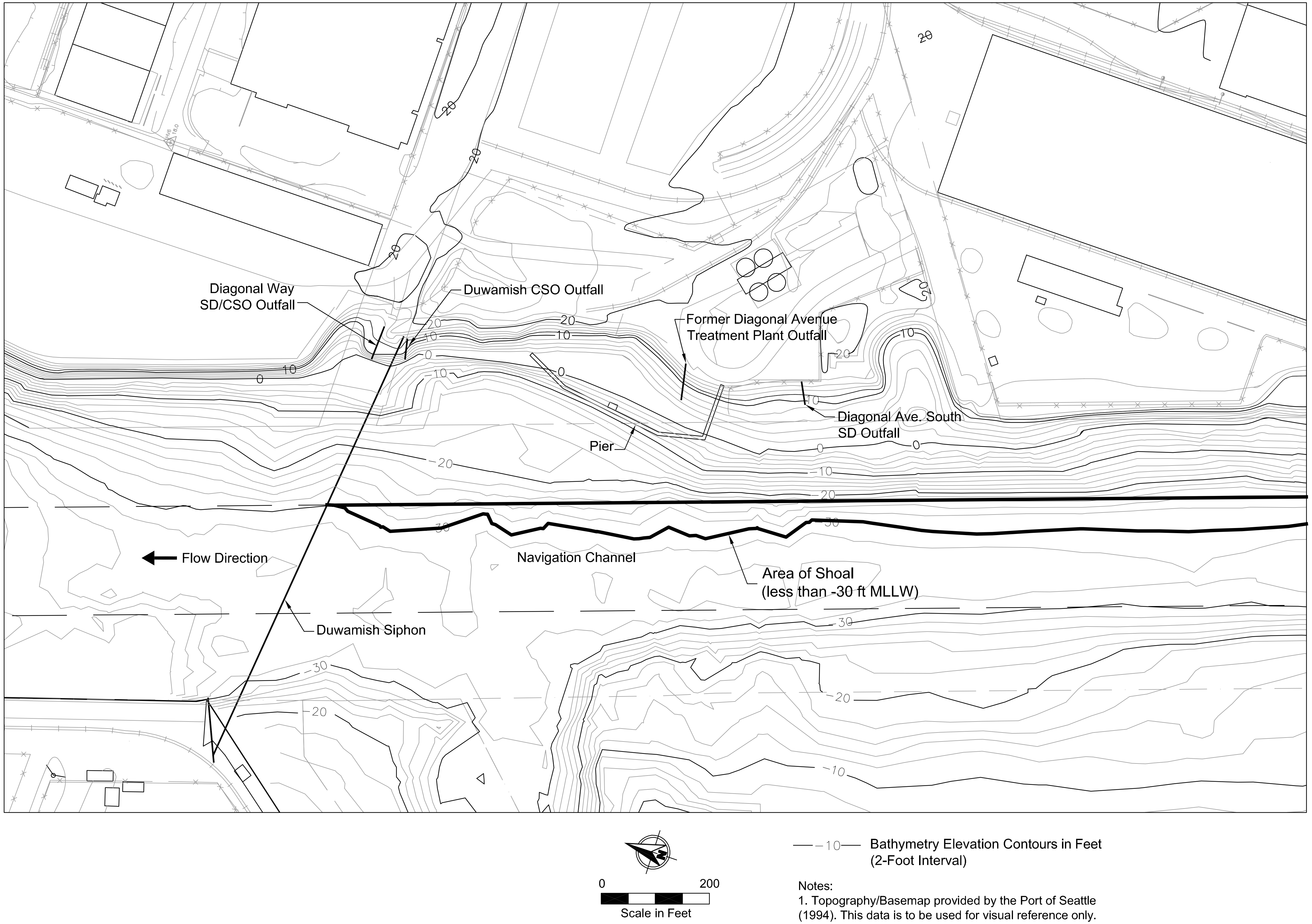


00-086-01

DWD021-01.dwg

12/20/01

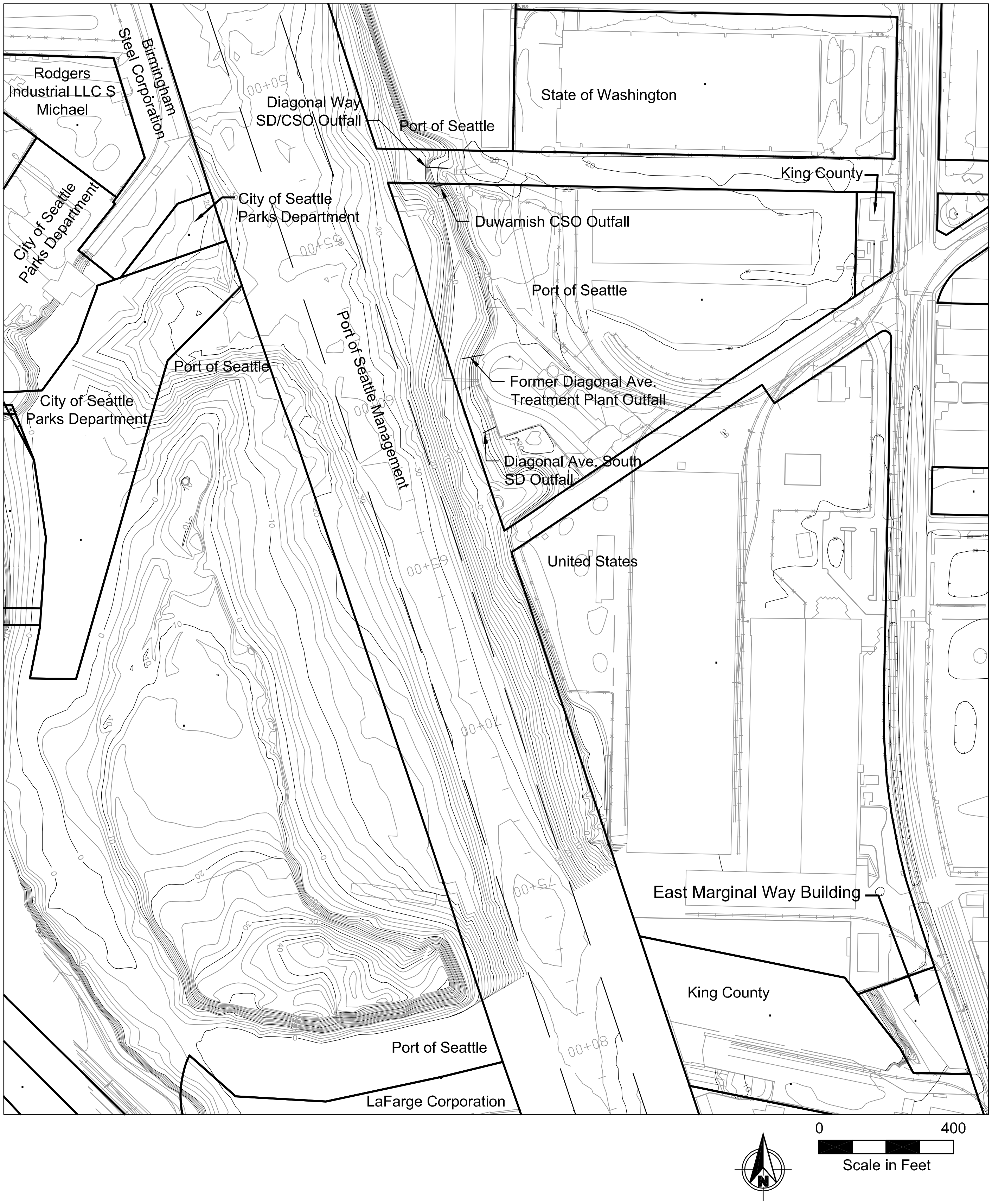
EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 2-5
	Duwamish/Diagonal Historic Activities	



Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from USACE 1997 survey referenced to MLLW (NOS).

00-086-01
DWD018-01.dwg
12/20/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Shoreline Features and Bathymetry	Figure 2-4

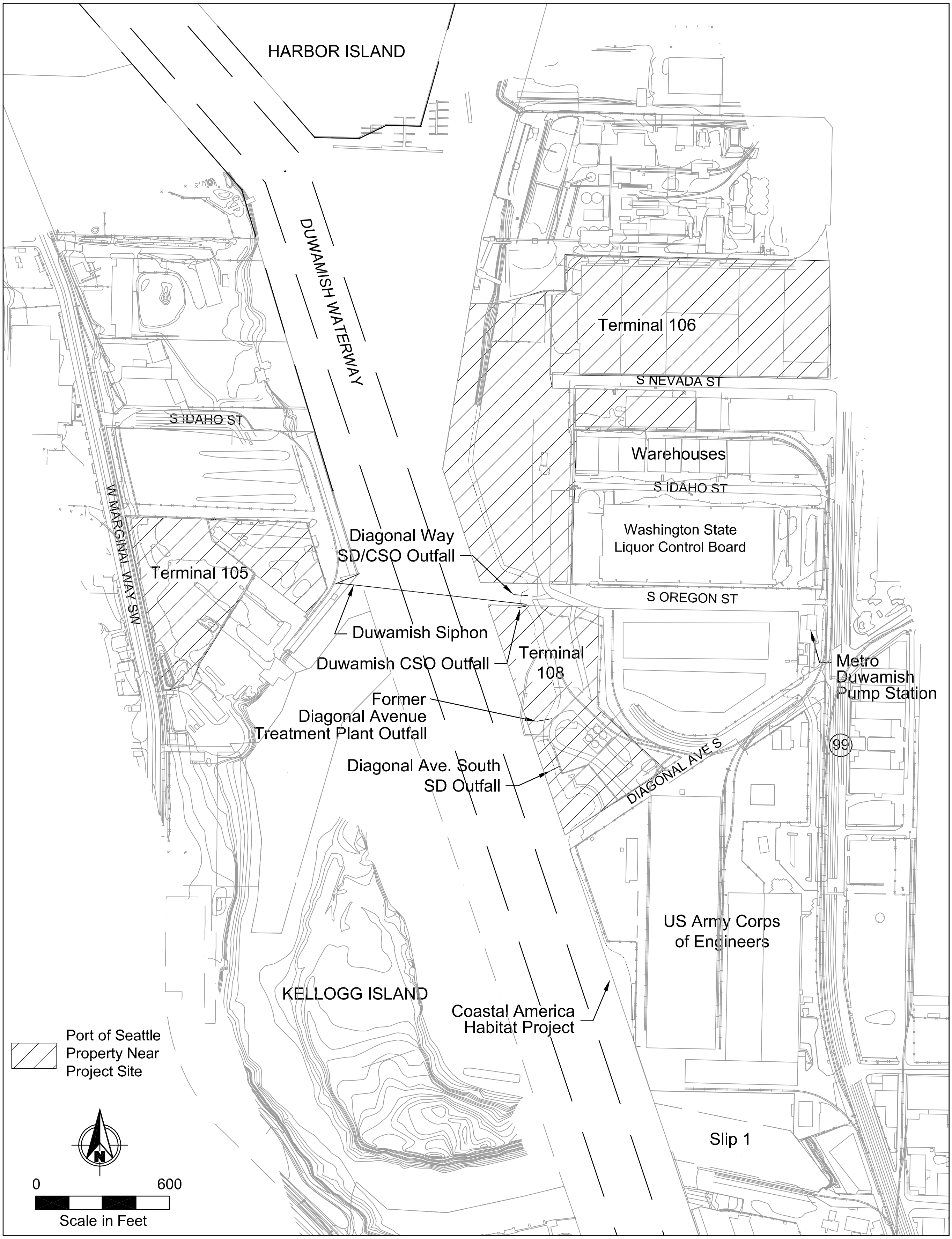


DWD023-01.dwg

00-086-01

12/14/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Property Ownership Map	Figure 2-3

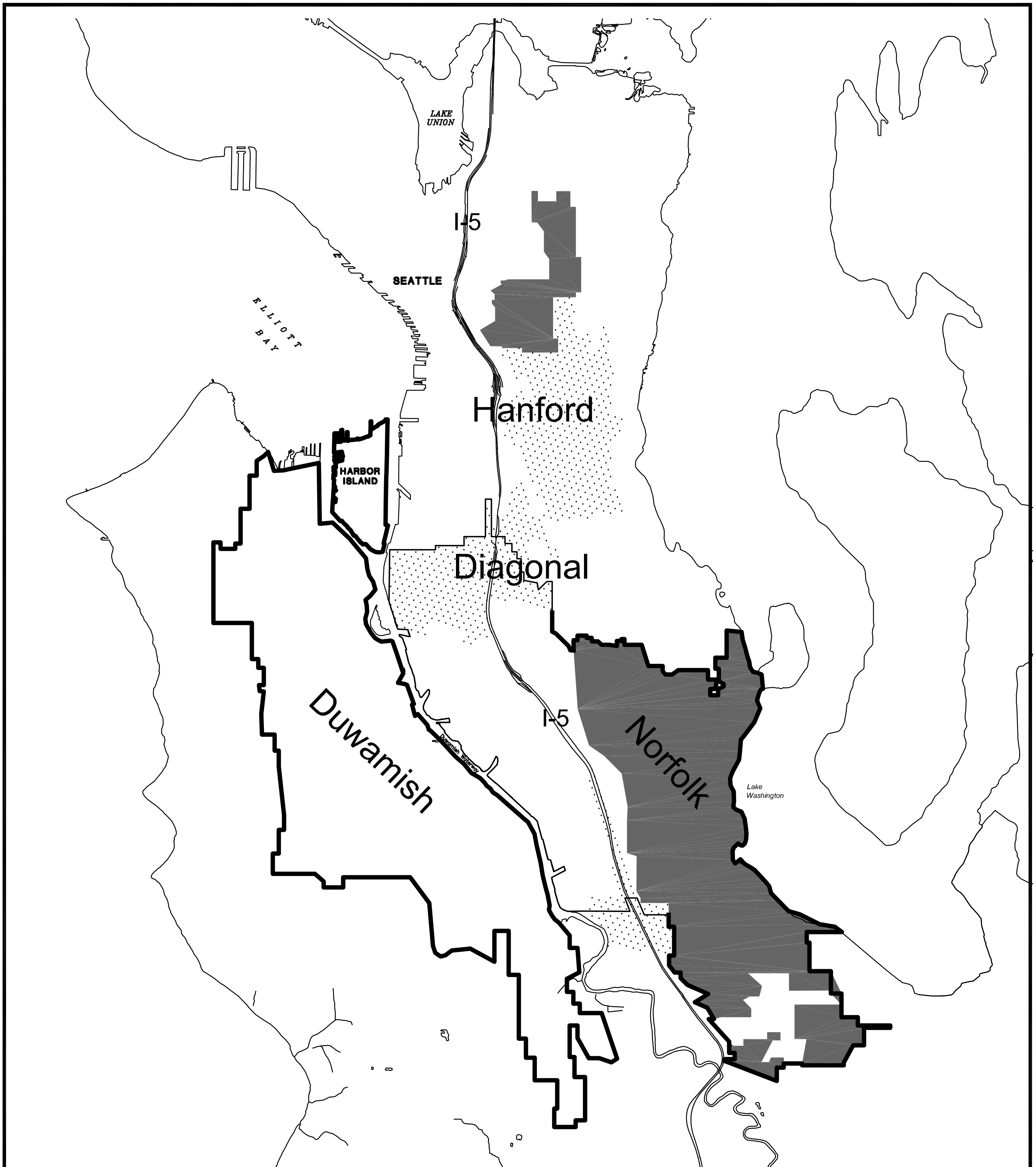


00-086-01

DWD017-01.dwg

12/20/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Duwamish/Diagonal Area Map	Figure 2-2



Source: Duwamish/Diagonal Cleanup Study Workplan, King County Department of Metropolitan Services, August 1994.

Note: In 1997 more detailed drainage maps were used to calculate the total annual storm water flow volume from the Diagonal/Hanford basin. Updated GIS maps should be obtained from either King County or the City of Seattle to insure accuracy in future decisions.

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 2-7
	Duwamish/Diagonal Drainage Basin Map	

00-086-01

DWD019-01.dwg

12/17/01

3.0 SOURCE CONTROL EVALUATION

3.1 COMBINED SEWER SYSTEM OVERVIEW

From the early 1900s to the mid-1940s or later, combined sewers were built to collect both sanitary sewage and stormwater in the various drainage basins. These combined sewers have been adequate for conveying dry-weather flows, but are inadequate to handle flows from heavy rainstorms. When flow exceeds the pipe and pumping capacity, the excess flow discharges directly into the receiving waters as combined sewer overflow (CSO) at overflow structures.

In the late 1950s, METRO (now KCDNR) was established to develop a regional approach to the conveyance and treatment of sanitary sewage from the Seattle area. The City transferred parts of the combined sewer system in its Southern Service Area to METRO. KCDNR provides conveyance and treatment services for the sewer systems associated with the Duwamish outfall and the City maintains sewer collection systems connected to the Diagonal outfall. Since the 1960s, KCDNR and the City have been constructing projects (including CSO control projects) in the Southern Service Area to improve water quality.

KCDNR oversees an extensive system of conveyance pipelines, regulator stations, and other wastewater facilities (KCDMS 1995). KCDNR's pipelines consist of force mains, trunk sewers, and interceptors. KCDNR trunk sewers pick up flows from the small collection pipelines and convey them to large-diameter interceptors that serve as the conduits for transferring flow to the treatment facilities. After treatment, treated effluent is discharged through outfall pipes to Puget Sound.

CSOs serve as safety valves for the sewer system. In combined sewer systems, the trunk sewers and interceptors have fixed capacities while wastewater flows vary with precipitation. During periods of intense or prolonged precipitation, wastewater flows may exceed the capacity of the sewer pipes to convey wastewater to the treatment plant. To prevent damage to the treatment plant and the backup of wastewater into homes and businesses, the lines are designed to overflow into receiving waters. The control point for overflows occurs at regulator stations.

Regulator stations were constructed by METRO in the early 1970s to control CSOs. They maximize the storage potential available in the large-diameter trunk sewers by shutting off flow to the interceptors during conditions of high storm flows. As a result, wastewater is forced to back up in the trunk sewers. When a trunk sewer reaches its specified storage capacity, an overflow gate is opened and the trunk sewer flow is released through an outfall structure as a CSO.

METRO instituted a formal CSO control program in 1979 under the impetus of the Federal Water Pollution Control Act Amendments of 1972 (KCDMS 1995). In 1987, Chapter 173-245 Washington Administrative Code (WAC) went into effect under the administration of the Washington Department of Ecology (Ecology), requiring reductions in CSO volumes to an average of one untreated discharge per year at each outfall. Chapter 173-245 WAC also requires CSO plans specifying the means of complying with the regulation. KCDNR and Ecology developed an interim goal of achieving an overall reduction of 75 percent in CSO volume throughout the KCDNR jurisdiction by the end of the year 2005. The *1988 Combined Sewer Overflow Control Plan* (METRO 1988) was developed to implement these CSO reduction goals. The *Combined Sewer Overflow Control Plan 1995* and *2000 Update Plans* (KCDMS 1995, KCDNR 2000) describe the current status and revised future plans. The City has achieved the required level of CSO control in the Duwamish watershed (City of Seattle 1996).

3.2 POTENTIAL CONTAMINANT SOURCES

Potential contaminant sources in the Study Area include stormwater and CSO outfalls, surface-water runoff, and groundwater inflow. Active outfalls include the Diagonal Way SD/CSO, and Diagonal Avenue South outfalls. The former Diagonal Avenue treatment plant outfall represents an historical discharge as does the Duwamish CSO, which has not had an overflow for over ten years. In addition, industrial discharges, dumping, and dredging operations may have contributed contaminants to the Study Area.

3.2.1 Diagonal Stormwater and CSO Outfall

The Diagonal SD/CSO outfall receives primarily stormwater and minor CSO flows from both the Diagonal and Hanford drainage basins. It is the City's largest stormwater outfall, handling runoff from approximately 1,583 acres of residential, commercial and industrial properties and approximately seven miles of I-5. The drainage basin contains hundreds of commercial and industrial businesses. Potential sources of contamination to the Diagonal SD/CSO outfall identified by the Elliott Bay Action Program (Tetra Tech 1988) include the former operations of Janco-United (which distributed degreasing compounds containing phthalates and chlorinated benzenes; see **Appendix G**); a machine shop; a tank cleaning service; a utility storage area; and the former Sixth Avenue South landfill. The landfill operated for thirty years prior to about 1955 and received dredged sediments from the lower Duwamish River (Duwamish Waterway). The current status of the landfill is unknown. A 1984 U.S. EPA investigation of Janco-United found high concentrations of phthalates, chlorinated benzenes, and volatile organic compounds in soils and drains at the facility. The investigation resulted in criminal charges and fines (EBDRP 1994b).

Sediment samples were collected from the Diagonal SD/CSO outfall in 1985 during the Elliott Bay Action Program. Pre-phase 1 data are included as **Appendix B**. Two sediment samples were collected in the Diagonal storm drainpipe; the first was at a manhole (Diag MH1) and the second was located approximately 25 feet upstream of the manhole (Diag MHU). These historic data for both samples were normalized for total organic carbon and compared to the state sediment standards adopted in 1991. At Station Diag MH1, there were 21 detected parameters that exceeded Washington Sediment Quality Standards (SQS), and eight of these also exceeded the Cleanup Screening Level (CSL). The eight compounds exceeding their CSLs were total low molecular weight polycyclic aromatic hydrocarbons (LPAHs), indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, benzo(g,h,i)perylene, 1,2-dichlorobenzene, 1,4-dichlorobenzene, phenol, and 4-methylphenol. At Station Diag MHU there were seven detected parameters that exceeded their SQSs, with five of these exceeding their CSLs. The five compounds exceeding the CSLs were mercury, 1,4-dichlorobenzene, dibenzofuran, total PCBs, and 4-methylphenol.

The City DWU sampled sediment from the Diagonal storm drain system in 1988, 1989, and 1994. The 1994 sampling results are presented in **Appendix G**. Results for the four sediment samples indicate no SQS exceedances for metals (arsenic, cadmium, chromium, copper, lead, mercury, silver, zinc). Concentrations of bis (2-ethylhexyl) phthalate exceeded the CSL criteria in three of four samples. An oily discharge has been observed from the Diagonal storm drain, and is also present in the muddy delta below the discharge. The oil is considered to be recent. The City DWU has attempted unsuccessfully to trace this oil discharge back to its source (**Appendix D**).

3.2.2 Duwamish CSO Outfall

The Duwamish CSO outfall is a relief point for combined sewage and stormwater that travels east under the river to the Duwamish Pump Station. Combined wastewater originates from the Delridge Trunk Sewer, the Chelan Avenue Regulator Station, and the East Marginal Way Pump Station. A combined sewer overflow event would be triggered only if the level in the pump station wet well exceeded a maximum set point.

Industries located in the Duwamish service area are potential dischargers of contaminants to the collection system. Seven industries permitted to discharge to the Duwamish sanitary sewer system are located on the West Side of the Duwamish Waterway. The permitted industries include a metal recycler, three metal finishers, a barrel-rinsing operation, stormwater discharge from a petroleum tank farm (ARCO on Harbor Island), and a stormwater and combined wood-preserving wastewater discharge (EBDRP 1994b). Seafab Metal Corporation on Harbor Island also has a discharge authorization to route some stormwater (from roof drains) to the sanitary sewer (EBDRP 1994b). This discharge was authorized to prevent direct discharge of contaminated stormwater to the waterway. In addition to permitted discharges and minor discharge authorizations, other minor discharges may result from commercial discharges (e.g., photo developers and gas stations; EBDRP 1994b).

No overflow conditions were observed for the pump station wet well during the period monitored from 1989 to the present. Consequently, discharges from the Duwamish outfall have not been sampled. Regular sampling of influent to the Duwamish Pump Station has been performed by KCDNR's Industrial Waste Section, but not during storm periods.

3.2.3 Diagonal Avenue South Storm Drain

The Diagonal Avenue South drain discharges runoff from a relatively small 12-acre basin adjacent to the Duwamish River and approximately 1,000 feet upstream of the Study Area. The basin is paved and has been used for storage by the surrounding properties (Tetra Tech 1988). A sediment sample (DiagS) was collected from the Diagonal Avenue South storm drain during the Elliott Bay Action Program. The data for this historic sample were normalized for total organic carbon and compared to Washington Sediment Quality Standards (**Appendix B**). At Station DiagS, four detected analytes exceeded SQS values, and one exceeded a CSL value (chromium). Because this drainage basin is less than one percent of the size of the Diagonal/Hanford drainage basin, total contaminant contributions from this outfall are expected to be minor.

3.2.4 Former City Treatment Plant Outfall

The former Diagonal Avenue treatment plant was located near the river about 150 m to the south (upstream) of the Diagonal SD/CSO outfall. The treatment plant was built by the City and began operation in 1940. Plant capacity was 7 to 8 million gallons per day (MGD) of primary treatment with only a two-hour wastewater retention time (EBDRP 1994b). METRO was formed in 1958 to improve sewage treatment in the Seattle area, and took over operation of the plant in 1962. This plant was operational until 1969 when the final stage of the Elliott Bay Interceptor pipeline was completed and flows were diverted to the West Point treatment plant. The Diagonal Avenue treatment plant treated wastewater from Seattle's primary industrial core and was considered to be one of the most overloaded plants in the Seattle system (EBDRP 1994b). Flow to the plant was limited by an upstream regulator that provided a bypass directly to the Duwamish River south of Slip 1 (Brown and Caldwell 1958). Due to the combined storm and sewer system, the plant frequently diverted untreated sewage into the Duwamish River during rain events (EBDRP 1994b). Treatment plant structures were removed in the mid-1970s, except for two below-ground clarifiers that were filled (AGI 1992). The sludge in the drying beds was covered with fill (AGI 1992) probably excavated from the near shore area when a berthing area was dredged in 1977.

A large portion of the contaminated sediment that may have been associated with the old treatment plant outfall appears to have been removed in 1977 when Chiyoda Corporation dredged a nearshore berthing area on the north side (downstream) of the old outfall. Chiyoda Corporation acquired the former treatment plant site in the mid-1970s. Little is known about Chiyoda Corporation's operations, except that it was a chemical company that wanted to develop a shore-based loading dock. They dredged the inshore area, but were unsuccessful at obtaining permits for the shore-based dock. Later, a mooring dock of piling clusters was built offshore.

In 1976, PCB-contaminated dredge spoils from a 1974 transformer fluid spill in Slip 1 (containing Aroclor 1242) were disposed on the Chiyoda property by the USACE (**Figure 2-5**; Sweet, Edwards & Associates and Harper-Owes 1985; AGI 1992). Two lagoons were excavated along the northern edge of the property in the former treatment plant sludge bed areas for treatment of approximately 10 million gallons of PCB-contaminated sediment dredged from near Slip1 (C-3, **Appendix C**). PCB-contaminated sediment was deposited primarily in the first receiving lagoon located closet to the river. Water pumped from the disposal lagoons was treated by particulate, sand, and charcoal filters prior to discharge to the Duwamish Waterway (AGI 1992). The PCB disposal pits were eventually backfilled with material from the excavation and additional sediment that Chiyoda dredged from the shoreline to improve berthing (AGI 1992).

The Port of Seattle acquired the Chiyoda property in 1980. The Port later sold part of the property to Chevron, retaining the portion along the river. Soil contaminated with petroleum hydrocarbons was stockpiled in the vicinity of the former disposal lagoons (AGI 1992). This soil was treated to meet the State of Washington TPH cleanup level of 200 mg/kg. The Port leased the southern part of the site to Lafarge Cement Company, which occupied the site from 1989-1998 and loaded cement barges at the mooring pile dock. This site is currently the Port of Seattle's Terminal 108 expansion area and is used for container storage.

3.2.5 Other Potential Sources

In 1974, a major PCB spill occurred near the Study Area when a transformer cracked while being loaded onto a barge in Slip 1. The location of Slip 1 is about 1,000 m (3,300 feet) upstream of the Duwamish/Diagonal outfalls. Approximately 250 gallons of near-pure PCB (Aroclor 1242) were spilled into the Duwamish River. The majority of this material was recovered during the dredging operations that followed the spill. PCB concentrations were monitored during the cleanup operation and mean concentrations were within the normal observed ranges. A report prepared for the USACE in 1978 concludes that, based on these monitoring results, the spill did not contribute a significant PCB loading to the lower Duwamish (USACE 1978). However, sediment samples taken by EPA in 1998 showed measurable levels of PCBs remain in the sediment in the dredged channel both upstream and downstream of Slip 1 (Weston 1999).

The Duwamish River is frequently dredged for navigational purposes (EBDRP 1994b). There is a potential for dredging operations to resuspend sediments, which could result in transport of contaminants to other areas. There is also a potential for contaminated sediments located downstream (e.g., at Harbor Island), to be transported upriver to the Study Area due to tidal action and movement of the salt wedge.

3.2.6 Surface Water Runoff

In the past, contaminants may have been carried to the vicinity of the Duwamish/Diagonal outfalls in surface water runoff from Terminal 106 and the former Chiyoda/Chevron property, but no information was found that documents contaminants in surface runoff from these areas. Current drainage patterns are unknown. Terminal 106 has a small surface drain (discussed in **Section 2.4.2**) that historically discharged along shore on the north side (downstream) of the Diagonal outfall, but more recently was connected to the Diagonal outfall; no drainage pipes were observed at Terminal 108. The presence of halogenated organic compounds and petroleum products was confirmed in surface water from the Coastal trailer repair site formerly located at Terminal 106 (EBDRP 1994b). A large part of the old treatment plant site has been paved over with asphalt for container storage, reducing the possibility that surface water will come in contact with contaminated sediments buried on the site.

Water column sampling for toxicants in the Duwamish River was performed by METRO in 1985. Copper, nickel, and lead concentrations measured in Duwamish River surface water samples collected downstream of the Duwamish/Diagonal outfalls, near the West Seattle Bridge and Harbor Island in 1985, exceeded the marine chronic Ambient Water Quality Criteria (AWQC) (METRO 1987). As part of the Duwamish River/Elliott Bay Water Quality Assessment, water samples were collected both upstream and downstream of the Duwamish/Diagonal outfalls between November 1996 and May 1997. However, no samples were collected directly off shore of the Duwamish/Diagonal outfalls. These samples were analyzed for metals, organics, nutrients, and microbiological parameters and a risk assessment was performed. There were no unacceptable risks attributed to chemical levels in the water column (KCDNR 1999).

3.2.7 Groundwater

Several potential sources of groundwater contamination exist. As discussed in **Section 3.2.4**, sludge and PCB-contaminated dredge spoils are buried in the vicinity of the former Diagonal Avenue treatment plant. PCBs and metals are typically identified as contaminants of concern at former sludge bed locations (EBDRP 1994b). Additionally, a groundwater study identified Ash Grove Cement, Seattle City Light Substation, ChemPro, Liquid Carbonic Corporation, and several refuse dumps, mounds, and waste pits as potential sources of groundwater contamination in the Study Area (Sweet, Edwards & Associates and Harper Owes, 1985).

Groundwater samples were collected from 14 wells at the Chiyoda/Chevron property located upstream of the Duwamish/Diagonal outfalls during October 1991 (dry season conditions) and January 1992 (wet season conditions) (AGI 1992). Groundwater is expected to flow to the Duwamish Waterway, but groundwater discharge rates and discharge points were not determined (AGI 1992). Hydraulic conductivity was not determined, but soil classification and observations during well construction suggest that the water-bearing portion of the fill has low permeability. Depth to groundwater ranges from 2 m to 4 m at the property. PCBs were not detected in groundwater samples (detection limit 0.1 µg/l), except in one duplicate sample. Aroclor 1248 was identified in this sample at a concentration of 0.3 µg/l. Because PCBs are not very mobile in groundwater and PCBs were generally undetected in groundwater samples, PCBs in groundwater are not expected to pose a risk to aquatic receptors in the waterway.

Polycyclic aromatic hydrocarbons (PAHs) were detected in Chiyoda/Chevron property groundwater samples. Total PAH concentrations measured in groundwater samples ranged from "not detected" in the southern portion of the property to 7.6 µg/l in the center of the property. PAH concentrations measured in groundwater samples exceed state guidelines (Model Toxics Control Act [MTCA] Method A). Diesel fuel and gasoline were measured in nine of 14 wells at concentrations ranging from 30 to 490 µg/l (AGI 1992). Few AWQC are available for PAHs for comparison, but the Lowest Observed Effects Level for total PAHs is 300 µg/l. Because total PAH concentrations were not measured in groundwater samples at levels exceeding the Lowest Observed Effects Level, it is unlikely that PAHs pose a risk to aquatic receptors in the waterway.

The maximum concentrations of cadmium (38 µg/l), copper (200 µg/l), lead (260 µg/l), mercury (0.3 µg/l), nickel (380 µg/l), and zinc (6,200 µg/l) measured in groundwater samples from the Chiyoda/Chevron property exceed ten times the marine chronic AWQC (AGI 1992). To be below AWQC, maximum concentrations of lead, nickel, and zinc would require dilution of over 45-fold before discharge to the waterway. It was not indicated whether the samples were filtered or unfiltered prior to analysis. Of the metals measured in groundwater at significant concentrations, only mercury has been detected in the preliminary sediment samples collected near the Duwamish/Diagonal outfalls at concentrations exceeding the Washington SMS.

3.3 STRUCTURAL IMPROVEMENTS AND WATERSHED SOURCE CONTROLS

If sediment in the vicinity of the Duwamish/Diagonal outfalls is remediated, adequate control of combined sewer overflows, storm drains, and industrial sources will also be necessary to prevent sediment recontamination. Structural improvements, as well as source controls, have been implemented for the Duwamish and Diagonal sewer and stormwater systems and are described below.

3.3.1 Duwamish CSO Outfall

Due to the configuration of the Duwamish outfall as an emergency overflow, CSO discharges are highly unlikely (EBDRP 1994b). No overflows have occurred since 1989, and none are anticipated in the future except under emergency conditions. Formal source control projects (other than periodic investigations and trouble call response by KCDNR's Industrial Waste and Water Resources staff) have not been conducted in the service areas tributary to the siphon (EBDRP 1994b). However, KCDNR's Local Hazardous Waste Management Program provides technical advice on proper industrial waste disposal methods to the Environmental Coalition of South Seattle, which provides information to local industries.

3.3.2 Diagonal SD/CSO Outfall

The Diagonal SD/CSO outfall receives flows from both the Diagonal and the Hanford drainage basins. There are a few local CSO points that can discharge into the stormwater system in the Diagonal basin, but these have been controlled by separation and storage to less than one overflow event per year. Part of the CSO control for the Hanford basin was the installation of a pipe within the Hanford Tunnel that transports sewage to the Elliott Bay Interceptor. Stormwater is conveyed separately to the Diagonal outfall. This separation project was completed in 1987 and was thought to have totally eliminated KCDNR's Hanford 1 CSO, which previously discharged over 300 million gallons per year at the Diagonal SD/CSO outfall. However, recent information has revealed that the Hanford 1 CSO is not totally controlled, but is now estimated to discharge about 20 times per year with a total annual average volume of about 65 MGY (Swarner personal communication 1999). Further work to control Hanford 1 is scheduled for early 2020, which is similar for all King County discharges to the Duwamish River.

Source control within the Diagonal and Hanford drainage basins is being implemented. The City DWU has completed a preliminary review of businesses in the basins to identify those likely to introduce pollutants or sediments into the stormwater system. Based on standard industrial classification codes, the City identified approximately 1,000 businesses, which could potentially conduct work outside or store materials outdoors. The majority of these businesses involved manufacturing, scrap yards, transportation, or automotive repair. Of these businesses, it was determined that more than 700 do not conduct outdoor activities that could potentially harm the environment (City of Seattle 1996). The remaining businesses were targeted for source control inspections (**Appendix D**). The objective of these inspections is to control contamination input from upland drainage basins by promoting best management practices, including disposal/storage activities and housekeeping practices, and to increase local awareness of the importance of protecting water quality.

The DWU also responds to reports from the public for inquiry or investigation of water quality problems in storm systems and streams (City of Seattle 1996). A review of DWU records produced only a small number of complaints for these two basins. For the years 1990 to 1994, twelve problems were reported in the Diagonal basin and nine in the Hanford basin (City of Seattle 1996). The majority of these complaints were related to fluid spills from private auto maintenance and illegal dumping of materials, with only one large spill being reported. The DWU has been actively engaged in increasing public awareness through source control inspections and newsletter mailings. Over the past few years several complaints have been raised about an oil sheen that is sometimes present in the discharge plume. In 1999, the City installed an oil containment boom at the Diagonal SD/CSO outfall and is continuing efforts to locate the source.

The removal of sediment from storm lines has also been identified as a method of reducing contaminant loadings to the Duwamish River. Seattle Engineering's Transportation Department has the responsibility for maintaining storm lines, catch basins, and storm sewer inlets in the City. DWU reviewed maintenance records for storm structures and estimated that approximately 1,300 and 1,400 inlets are within the Diagonal and Hanford basin boundaries, respectively. Historical maintenance records document yearly checks of inlets for sediment depth, with scheduled pump-outs usually on alternate years. The DWU intends to implement a Diagonal storm drain sediment clean-out project in conjunction with the Duwamish/Diagonal sediment cleanup effort (**Appendix D**).

3.4 RECONTAMINATION MODELING RESULTS

Sediment recontamination modeling was conducted on three separate occasions, using two different methods, in attempts to characterize the likelihood of recontamination of the sediment in the Study Area following cleanup. If the modeling results indicated the potential for recontamination of the sediment by these sources, additional source control or treatment measures would need to be considered for the Diagonal/Duwamish basin.

The first modeling effort was undertaken in 1996 by KCDNR, using a modification of the SEDCAM model they named METSED. This modeling had to be modified in 1997, when new information from the City significantly increased the assumed stormwater discharge for the Diagonal SD from an estimated annual flow of 685 MGY to 1230 MGY. These assumptions and observations are summarized in Section 3.4.1. The full modeling report, including the update information is presented in **Appendix H.**

The second effort was conducted by WEST Consultants in 1999, using direct field observations, supplemented by analytical and numerical results, to perform a mass balance between the chemicals observed in the "footprint" and the various sources, including background. Their assumptions and observations are summarized in Section 3.4.2. The full modeling report is presented in **Appendix I**.

3.4.1 METSED Model - KCDNR

Sediment recontamination modeling was conducted by KCDNR to evaluate the likelihood of recontamination of the sediment at the site after sediment cleanup has occurred. Modeling results are included as **Appendix H**. The potential concentration increase of various sediment contaminants in the cleaned area near the discharge was to be modeled.

The model used for the evaluation is based on SEDCAM (Ecology 1991). It was modified by KCDNR staff and renamed METSED. METSED assumes that chemicals discharged to the receiving water (the Duwamish River) are well mixed in a control volume overlying the sediments. Assuming the ambient flow of water in the river, the concentration of chemicals entering the control volume, the CSO/SD discharge flow rate, and concentrations of the same chemicals in the discharge, the model computes the exchange between the water column and the underlying sediment to estimate sediment concentrations. Processes modeled include mass accumulation, constituent decay, and chemical partitioning.

In applying METSED, it was assumed that discharge from the Diagonal outfall would mix into a fraction of the Duwamish River, characterized by a mixing zone width. Particle size distributions and settling velocities were obtained from the USACE Duwamish River Navigation Improvement Study (USACE 1981). The average flow in the Duwamish River was assumed to have a constant discharge per unit width. Discharge concentrations were specified using CSO data collected by METRO at a number of area CSO sites. For some chemicals, these average CSO concentrations tended to be higher than average stormwater concentrations collected in the Diagonal drainage basin; therefore, use of the average CSO concentrations in the recontamination model is considered a more conservative analysis.

The conclusion of this modeling effort by KCDNR is that cleaned sediment in the vicinity of the Duwamish/Diagonal outfalls would likely be recontaminated above the SQS by bis (2-ethylhexyl) phthalate and butyl benzyl phthalate. This modeling approach was not totally consistent because it also predicted that two metals would pose a greater recontamination potential than the two phthalates. However, the measured surface sediment concentrations at the site showed that these two metals did not exceed the SMS values as was predicted by the model. This conclusion led to further modeling, using another approach, in an effort to confirm or refute these findings.

3.4.2 Mass Balance Model - By WEST Consultants

A basic mass balance modeling approach was selected because it relies on the simplest assumptions and is based primarily on field observations, supplemented by numerical modeling results, to define the relationship between discharges from the storm drains and combined sewer overflows and the nearby sediment. This approach was used to determine the discharge load reduction necessary for each constituent to maintain sediment quality compliance in the Duwamish/Diagonal footprint following cleanup. Various approximations and estimates were required to establish input values for the following parameters:

- Average discharge volumes from storm drains and combined sewer overflows,
- Discharge sediment loads,
- Discharge constituent concentrations,
- Mass of discharged constituents deposited beyond the “footprint,” and
- Background river loading.

Assumptions included:

- Sediment from the storm drains and combined sewer overflows settle in the same proportion as measured in their respective discharges,
- There are no chemical transformations or decay on the sediment,
- Background deposition is uniform and known, and

- The “footprint” is in equilibrium with existing discharges.

Once the model was run to “validate” these estimates and assumptions, the model was rerun to solve for storm drain and combined sewer overflow constituent concentrations that would be necessary to maintain sediment quality compliance after cleanup. The full modeling report is included as **Appendix I.**

The study area for the model was the Duwamish River in the vicinity of the Diagonal outfall. The chemicals modeled included chrysene, fluoranthene, pyrene, bis (2-ethylhexyl) phthalate, butyl benzyl phthalate, and 1,4-dichlorobenzene. Sediment data used in the modeling came from the findings of this Duwamish/Diagonal Site Assessment study (**Appendix A**). Data from the KCDNR were used to estimate combined sewer overflow and storm drain discharge rates and discharge contaminant concentrations. The background sediment deposition rate, 2.8 cm/yr, was determined from the results of the three-dimensional circulation and sediment transport modeling performed by the KCDNR. When the background of 2.8 cm/yr is subtracted from the rate of sedimentation in the footprint of 3.5 cm/yr, the outfalls were assumed to contribute the difference of 0.7 cm/yr. Background sediment concentrations for each constituent were developed by averaging the measured concentrations at two points beyond the “footprint.”

The results of this modeling effort indicate that chrysene, fluoranthene, pyrene, and 1,4-dichlorobenzene will not exceed the SQS after cleanup (i.e., recontamination is unlikely to occur). For butyl benzyl phthalate however, recontamination is indicated, even if discharge from the storm drain is completely eliminated. Virtually the same is true for bis (2-ethylhexyl) phthalate. Depending on the background concentration assumed for bis (2-ethylhexyl) phthalate, upwards of 87 percent of the source would have to be elinminated to maintain sediment concentrations below the SQS after cleanup.

The report also identifies important limitations to this method imposed by the available data. Improved knowledge of settling rates near the discharges, chemistry of the discharges, and chemistry of the background sediment would greatly reduce the uncertainties present in the current analysis. However, simulation of the complex physical and chemical processes that create the “footprint” from the various discharges will remain difficult.

3.4.3 Factors Supporting Remediation

Achievement of adequate source control prior to remediation is the ideal project goal. However, there are at least four factors that come into consideration when assessing whether a sediment remediation action should proceed despite high potential for recontamination.

1. What is the feasibility of achieving source control to remove the problem chemical?
2. Is there information that indicates the problem chemical is actually less toxic than predicted by the SMS value?
3. Is the predicted recontamination area small compared to the entire remediation area?
4. Does remediation remove chemicals of greater concern than the chemicals that are predicted to recontaminate the site?

Consideration of these factors could support moving ahead with the project and they are discussed further in **Section 5.4**.

4.0 DATA COLLECTION AND RESULTS

4.1 STUDY OBJECTIVES

The overall objective of the data collection effort was to characterize the spatial extent and magnitude of sediment contamination resulting from the discharge of the Duwamish/Diagonal CSO/SD outfalls into the Duwamish River. Chapter 4 discusses the data collection and results of KCDNR work. The 1998 EPA data (Weston 1999) is included in data interpretation where available.

KCDNR staff conducted field sampling over three phases. Specific objectives of each phase of the KCDNR study are summarized in **Table 4.1**.

Table 4.1 STUDY OBJECTIVES

Phase	Sample Period	Primary Objectives
1	August 9-20,1994	1a. Determine the areal extent of sediment contamination near the outfalls based on comparison of surface chemistry data to SMS criteria. 1b. Supplement surface chemistry results with bioassay data to provide information used to assess risks to natural resources and confirm that contaminant concentrations are of concern. 1c. Collect sediment cores to determine vertical extent of contamination.
1.5	November 7-11, 1995	1.5a. Refine the boundary of the sediment cleanup area around the outfalls based on additional surface chemistry characterization.
2	May 20-21, June 3, 1996 July 22-26, 1996 September 9-11, 1996	2a. Collect additional sediment cores to refine vertical extent of contamination. 2b. Refine the boundary of the sediment cleanup area around the E-shaped pier and Diagonal South outfall based on additional surface chemistry characterization. 2c. Refine the boundary of the sediment cleanup area around the outfalls based on bioassay testing and additional surface chemistry characterization.

4.2 FIELD AND LABORATORY METHODS

This section briefly describes the field and laboratory methods utilized during the KCNDR Duwamish/Diagonal outfall characterization. For a detailed description of study design, field procedures, and analytical methods, refer to the following documents:

- EBDRP (1994c). *Duwamish/Diagonal Sampling and Analysis Plan*. Prepared for EBDRP by King County Department of Metropolitan Services. September 1994.
- EBDRP (1996a). *Duwamish/Diagonal Phase II Sampling and Analysis Plan.* Prepared for EBDRP by King County Department of Metropolitan Services. April 1996.

- Weston (1999). *Site Inspection Report, Lower Duwamish River (RK 2.5 to 11.5), Seattle, Washington*. Prepared for the U.S. Environmental Protection Agency, Region 10. Seattle, Washington. April 1999.

The Duwamish/Diagonal Sampling and Analysis Plans (SAPs) were developed in accordance with requirements of the SMS and the *Sediment Cleanup Standards User Manual* (Ecology 1991), and were reviewed and approved by the SRTWG and the EBDRP Panel prior to implementation.

4.2.1 Field Methods

KCDNR staff performed all field sampling during Phases 1, 1.5, and 2. Specific elements of the field studies are summarized below. Field methods used during the EPA study are summarized in their report (Weston 1999).

4.2.1.1 Sampling Design

The sampling design for the Phase 1 sediment chemistry surface grab stations was based on depth contour strata and systematic spacing. Four strata were chosen that run approximately parallel to shore: 1) intertidal mudflat northeast of the Diagonal outfall; 2) the area between 0 feet (MLLW) and -10 feet (0 to 3 m); 3) the area between -10 feet and -25 feet (MLLW) (3 to 8 m); and 4) the area deeper than -25 feet (MLLW) (8 m) and to the east edge of the dredged channel. From the outfall, the sampling grid extended approximately 300 feet downriver, 800 feet upriver, and 200 feet offshore, at 100 foot (33 m) intervals.

Focused sampling designs were applied to the Phase 1.5 and Phase 2 field efforts to refine the boundaries of the contaminated areas. Phase 1.5 stations were outside or on the perimeter of the Phase 1 sampling design to assess the extent and composition of pollutants at distance from the outfalls. The Phase 2 Study Area was divided into three areas: 1) downstream (to the north), where the surface boundary would be defined by biological testing; 2) the vicinity of the E shaped pier at the cement shipping facility, where relatively minor contamination would be evaluated using biological testing; and 3) upstream (to the south), where chemistry testing would be used to refine the boundaries of an area with high concentrations and different chemicals than identified in the other areas.

Sediment cores were collected during Phase 1 and Phase 2 to assess the vertical extent of contamination and estimate the volume of contaminated sediments. This information was necessary to support design of dredging plans and the evaluation of disposal options. Two cores directly offshore of the Duwamish and Diagonal outfalls were taken during Phase 1. Phase 2 cores were taken throughout the near shore area that was considered to have the highest potential for remediation. No cores were taken in the dredged river channel because it was assumed the area would eventually be dredged by the USACE.

4.2.1.2 Surface Sediment Collection

Surface sediment chemistry and bioassay samples were collected with a 0.1 m^2 van Veen grab. A 10-cm deep subsample from the center of the grab sample was taken for analysis. Two grabs were composited at each station to form one sample where only sediment chemistry analyses were performed. Samples for both chemistry and bioassay analyses were composited from three grabs. Samples were rejected if they failed to meet sample acceptability criteria specified in *Puget Sound Estuary Program Protocols* (PSEP 1991), and the *Duwamish/Diagonal Sampling and Analysis Plans*. (EBDRP 1994c; EBDRP 1996a)

Sediment grab samples were processed according to the following sequence, when applicable:

1. Total sulfides, acid volatile sulfides, and pH/Eh/temperature measurements were conducted on the first acceptable grab.
2. The top 10 cm was then composited from several grabs.
3. Sample containers were then filled in the following order from the composite: (a) methyl mercury, (b) metals, (c) organotins, (d) BNA (Base/Neutral/Acid)/pesticides/PCBs, (e) chlorinated benzenes, (f) PCB congeners, (g) percent solids and total organic carbon, (h) particle size distribution, (i) interstitial salinity, and (j) bioassays.

Samples were kept on board in ice chests and transported to the King County Environmental Laboratory (KCEL) at the end of each field day, where they were stored in accordance with conditions specified in the Duwamish/Diagonal SAP.

The van Veen grab sampler was cleaned between stations using the following sequence: 1) soap and water scrub, 2) triple rinse with site water, and 3) final in-stream site water rinse. These procedures were an exception to the PSEP protocols, but were implemented to avoid the use of both acetone and methylene chloride in the field. Stainless steel bowls and utensils were cleaned at the laboratory prior to field use.

4.2.1.3 Subsurface Sediment Collection

Sediment cores were collected by three methods. During Phase 1, a thin-walled, 4-inch (10-cm) diameter aluminum core tube was driven vertically into the sediments by a diver using a pneumatic jackhammer. The two cores (DUD006, DUD020) were divided into 6-inch (15-cm) segments for analysis. Every 6-inch section was analyzed within the top three feet of the core and every other 6-inch section was analyzed within the bottom two feet of the core.

Phase 1 cores were processed according to the following sequence:

1. Determine the top and bottom of the sediment within the core; divide the core into 6-inch sections accordingly. Extrude the sample and exclude the sediment in contact with the edges and ends of each section.

2. Obtain a sample for acid volatile sulfides from the entire length of each 6-inch section.

3. Mix the remaining sample from each section thoroughly. Sample containers were then filled in the following order from the mixture: a) BNA/pesticides/PCBs, b) metals, c) percent solids and total organic carbon, and d) particle size distribution.

Two methods of coring were employed during Phase 2. The core at station DUD206 was obtained using a hand auger during a low tide. The other cores were obtained with a vibracorer operated remotely from a vessel by the contractor, Marine Sampling Systems, with KCDNR personnel aboard. Cores were divided into compaction-corrected 3-foot (0.91 m) sections at the laboratory. Some sections of cores were archived based on the following scheme: 1) the bottom section (i.e., 6 to 9 feet) was archived for cores within the most contaminated areas; 2) the two lowest sections (i.e., 3 to 6 feet and 6 to 9 feet) were archived for cores far downstream of the Duwamish/Diagonal outfalls or within the central unit where contamination was lower. The archived samples were kept for possible future analysis. Most of the archived samples were eventually analyzed for PCBs and conventionals.

Two of the Phase 2 cores (DUD027 and DUD254) were analyzed for disposal option tests in addition to more routine analyses. The Phase 2 cores were processed according to the following sequence:

1. Divide the core into compaction-corrected 3-foot (0.91 m) sections. Extrude the sample and exclude the sediment in contact with the edges and ends of each section.

2. Obtain samples for TCLP-volatiles, TPH-gasoline, and reactivity from the undisturbed entire length of each section.

3. Mix the remaining sample thoroughly.

Sample containers were then filled in the following order from the mixture: a) BNA/pesticides/PCBs, b) chlorobenzenes, c) metals, d) percent solids and total organic carbon, e) particle size distribution, f) TCLP-organics and TCLP-metals, g) TPH-HCID, and h) ignitability and corrosivity. Core sections were assigned unique laboratory numbers. Cores were kept onboard and transported to KCEL at the end of each field day, where they were processed and individual samples were stored in accordance with conditions specified in the Duwamish/Diagonal SAP.

The procedure used to section Phase 1 cores differs in two significant ways from that used for Phase 2. First, Phase 1 cores were sectioned into 6-inch sections, compared to the 3-foot sections of Phase 2. Second, Phase 2 core sections were corrected for compaction (difference between penetration and recovery) while the Phase 1 sections were not. For these reasons, Phase 1 and Phase 2 core sections are not directly comparable.

All coring equipment was cleaned prior to field sampling. Core tubes were cleaned using the following sequence: 1) soap and water scrub, 2) triple rinse with tap water, and 3) final in-stream site water rinse.

4.2.1.4 Reference Stations

Two reference samples were collected by KCDNR during Phase 2 to assist with bioassay interpretation. The reference stations (CR101, CR102) were established at Carr Inlet in areas with known sediment quality and successful toxicity reference sediments where interstitial salinities and grain sizes would be similar to sediments at the investigation site. CR101 was established for comparison to sediments with a high percentage of fines, which includes six of the seven-bioassay samples taken from

Duwamish/Diagonal. CR102 was established for comparison to coarse sediments, in this case, the sample from DUD206.

4.2.1.5 Station Positioning

During Phase 1 and Phase 1.5, shore-based surveyors directed the survey vessel to pre-determined sampling stations. Surveyors used a combined theodolite and infrared electronic distance measuring instrument (EDMI) manned at shore reference stations. The EDMI targeted onto an Omni prism cluster mounted on the survey vessel, and the survey vessel was directed to within +/- 3m of the pre-determined station. The sampler was deployed when the vessel was in an acceptable location and the surveyors recorded the position of the vessel after the grab sampler (or diver) hit bottom. Measured angles and ranges were converted to horizontal plane coordinates referenced to the Washington coordinate system, north zone, 1983 North American Datum (NAD83). Depths are referenced to MLLW, with corrections based on tide tables.

A Differential Global Positioning System (GPS) was used for positioning during Phase 2 grab and core sampling operations. The Coast Guard base station was used for real-time corrections, allowing approximately 1-m accuracy. During grab sampling, the GPS receiver antenna was mounted atop the crane deploying the instrument, negating the need for offset calculations. Grab sampling locations should be accurate within 10 feet (3 m). The GPS antenna was mounted above the cabin during coring, requiring a correction based on a recorded compass bearing and assumed 30-foot offset. Coring locations are expected to be accurate within 20 feet (7 m). Depths are referenced to MLLW with corrections based on tide tables.

Station locations for Phase 1, Phase 1.5, Phase 2, and EPA stations in the study area are illustrated in **Figure 4-1.** Overall, a total of 58 surface sediment stations and 14 sediment core stations were sampled during the KCDNR investigation. Actual station coordinates and sediment elevations are presented in **Appendix J**.

4.2.1.6 Field Documentation

KCDNR sample documentation included 1) chain-of-custody forms, which were maintained throughout the laboratory analyses; 2) field sheets maintained by the KCEL; and 3) sampling notes maintained by the Project Manager. Sampling notes are not available for the Phase 2 bioassay samples.

4.2.2 Laboratory Methods

Laboratory methods were selected to provide data for comparison to SMS criteria. In addition, some sediments were tested for waste classification to evaluate disposal and beneficial use options. The KCEL conducted most of the chemical testing, however, KCEL also subcontracted some analyses to the following laboratories: (1) Beak Consultants of Kirkland, Washington; (2) AmTest Inc., of Redmond, Washington; (3) Frontier Geosciences of Seattle, Washington; (4) MEC Analytical Systems, Inc., of Carlsbad, California; (5) Battelle Marine Sciences Laboratory of Sequim, Washington; and (6) Laucks Testing Laboratories, Inc., of Seattle, Washington.

Test methods and laboratories used for this study are presented in **Table 4.2**. Because not all test methods were conducted during each phase, a complete log of analyses performed on each sample, at each station, during each phase is included in **Appendix K.**

Holding times and detection limits for this study were specified in the Sampling and Analysis Plans (EBDRP 1994c and 1996a). Holding times were based primarily on Ecology guidance originating from the *PSDDA Third Annual Review Meeting* (ARM 1991). The KCEL distinguished between a method detection limit (MDL) and a reporting detection limit (RDL) for most analyses. The MDL represents the lowest concentration at which sample results are provided and the RDL is defined as the minimum concentration of a constituent that can be reliably quantified. For this report, the MDL value was used to represent the limit of detection. Some data (e.g., particle size, reactivity, and methyl mercury) are available with an MDL only, in accordance with laboratory policies. Ignitability, corrosivity, and WTPH-HCID results are qualitative, so their reporting requirements are different.

Table 4.2 TEST METHODS AND LABORATORIES

Parameter	Method	Laboratory
Conventionals:		
Acid Volatile Sulfides	PSEP	AmTest
Total Solids	SM 2540-B	KCEL
Total Organic Carbon (TOC)	SM 5310B, PSEP Prep	KCEL
Ammonia Nitrogen	SM 4500-NH3-N	KCEL
Particle Size Distribution (PSD)	PSEP/ASTM 422	AmTest
Interstitial Salinity	Refractometer	Beak (Phase 1) MEC (Phase 2)
Metals:		
Total Metals	EPA 3050/6010; Inductively Coupled Plasma	KCEL
Total Mercury	EPA 7471; Cold Vapor Atomic Absorption	KCEL
Methyl Mercury	In-house method	Frontier Geosciences
Organics:		
Base/Neutral/Acid Extractable (BNAs)	EPA 3550/8270	KCEL
Polychlorinated Biphenyls (PCBs)	EPA 3550/8080	KCEL
Chlorinated Pesticides	EPA 3550/8080	KCEL
Tributyltin	Grignard (NOAA 1989) (Unger et al. 1986)	Laucks (Phase 1) Battelle (Phase 1.5)
Chlorinated Benzenes	EPA 3550/8270; and ion trap detector or SIM	KCEL
Waste Characterization:		
Total Petroleum Hydrocarbons	WTPH-HCID	KCEL
TCLP-Volatiles, BNAs, Pesticides, Metals	EPA SW-846	KCEL
Reactivity-Cyanide and Sulfide	EPA SW-846	AmTest
Ignitability and Corrosivity	EPA SW-846	AmTest
Bioassays:		
Amphipod (*Eohaustorius estuarius)*	10-d mortality; PSEP 1995	Beak (Phase 1)
Amphipod (*Rhepoxynius abronius*)	10-d mortality; PSEP 1995	MEC (Phase 2)
Echinoderam *(Dendraster excentricus)*	Larval mortality/abnormality; PSEP 1995 (Phase 1);	Beak (Phase 1) MEC (Phase 2)

Parameter	Method	Laboratory
	PSEP 1995 (Phase 2)	
Polychaete *(Neanthes arenaceodentata)*	20-d growth; PSEP 1995 (Phase 1); PSEP 1995 (Phase 2)	Beak (Phase 1) MEC (Phase 2)

Collection, analysis, and reporting of sediment toxicity (bioassays) were conducted in accordance with PSEP (1995) and WAC 173-204-315, -320 and -520 (Ecology 1995a). The bioassay test organisms were selected based on grain size, interstitial salinity, and tributyltin tolerance. Most of the bioassays were performed on sediments with 50 to 97 percent fines, with one as low as 8 percent fines. Interstitial salinity values of 21 to 33 parts per thousand were measured at the site; based on this range, it was appropriate to use marine bioassays and adjust salinity upward as needed to meet the testing protocols of 25 parts per thousand. High concentrations of tributyltin (>400 ppb), which could potentially cause toxicity unrelated to SMS-criteria parameters, were found at the perimeter of the site.

West Beach sand was collected from Whidbey Island, Washington, for use as a negative control in the polychaete and amphipod test. Seawater was used for the negative control for the echinoderm test. Reference sediments for all three organisms were collected from Carr Inlet, Washington. Positive controls with cadmium chloride were conducted for all three organisms.

4.3 QUALITY ASSURANCE / QUALITY CONTROL RESULTS

KCEL prepared a Quality Assurance (QA) review for data collected and analyzed during Phases 1, 1.5, and 2. The QA1 reviews were conducted in accordance with guidelines established through the Puget Sound Dredged Disposal Analysis (PSDDA) program, primarily in the *PSDDA Guidance Manual, Data Quality Evaluation for Proposed Dredged Material Disposal Projects.* Additionally, many of the approaches incorporated in the QA1 reviews have been established through collaboration between KCEL and Ecology's Sediment Management Unit.

Laboratory QA1 reports include:

- Metro Environmental Laboratory Quality Assurance Review for Duwamish/Diagonal Sediment Cleanup Study, Elliott Bay Duwamish Restoration Program, December 23, 1994 (Phase 1).
- King County Environmental Laboratory Quality Assurance Review for Duwamish/Diagonal CSO, Pre-Phase II Marine Sediment Sampling, December 28, 1995.
- King County Environmental Laboratory Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study, Phase II Marine Sediment Core Sampling, August 21, 1996.
- King County Environmental Laboratory Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study Phase II Marine Sediment Grab Sampling and Study, Phase II Marine Sediment Core Sampling, November 12, 1996.
- King County Environmental Laboratory Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study, Phase II Archived Sediment Core Samples, February 7, 1997.

Table 4.9 WASTE CHARACTERIZATION RESULTS

Sample ID	Dangerous Waste Regulations		DUD027		DUD027		DUD027-Rep.		DUD027-Rep.		DUD254		DUD254	
Laboratory ID			L8542-35		L8542-36		L8542-37		L8542-38		L8542-19		L8542-20	
Sample Depth (cm)			0-90		90-180		0-90		90-180		0-90		90-180	
Sample Date			5/21/96		5/21/96		5/21/96		5/21/96		5/21/96		5/21/96	
	DW	EHW	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.
Metals (mg/L)														
Arsenic, Total	5	500	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Barium, Total	100	10000	0.0818		0.0515		0.0819		0.198		0.14		0.222	
Cadmium, Total	1	100	0.003	U	0.0042	J	0.003	U	0.003	U	0.003	U	0.003	U
Chromium, Total	5	500	0.015	J	0.005	U	0.02	J	0.0094	J	0.007	J	0.0089	J
Lead, Total	5	500	0.03	U	0.03	U	0.03	U	0.03	U	0.418		0.03	U
Mercury, Total	0.2	20	0.0002	U	0.0002	U	0.0002	U	0.0002	U	0.0002	U	0.0002	U
Selenium, Total	1	100	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Silver, Total	5	500	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U
Organics (ug/L)														
Benzene	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
Carbon Tetrachloride	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
Chlordane	0.03	3	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U
Chlorobenzene	100	10000	1	U	1	U	1	U	1	U	1	U	1	U
Chloroform	6	600	1	U	1	U	1	U	1	U	1	U	1	U
2-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
3-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
4-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.99		0.47	U
2,4-D	10	1000												
1,4-Dichlorobenzene	7.5	750	0.28	U	0.28	U	0.31	J	0.37	J	1.16		0.47	J
1,2-Dichloroethane	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
1,1-Dichloroethylene	0.7	70	1	U	1	U	1	U	1	U	1	U	1	U
2,4-Dinitrotoluene	0.13	13	0.19	U	0.19	U	0.19	U	0.19	U	0.19	U	0.19	U
Endrin	0.02	2	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Heptachlor	0.008	0.8	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Heptachlor Epoxide	0.008	0.8	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Hexachlorobenzene	0.13	13	0.28	U	0.28	U	0.28	U	0.28	U	0.28	U	0.28	U
Hexachlorobutadiene	0.5	50	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Hexachloroethane	3	300	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Gamma-BHC (Lindane)	0.4	40	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Methoxychlor	10	1000	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U
2-Butanone (MEK)	200	20000	5	U	5	U	5	U	5.1	J	5	U	5	U
Nitrobenzene	2	200	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Pentachlorophenol	100	10000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Pyridine	5	500	2.8	U	2.8	U	2.8	U	2.8	U	2.8	U	2.8	U
Tetrachloroethylene	0.7	70	1	U	1	U	1	U	1	U	1	U	1	U
Toxaphene	0.5	50	0.24	U	0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Trichloroethylene	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
2,4,5-Trichlorophenol	400	40000	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U
2,4,6-Trichlorophenol	2	200	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U
2,4,5-TP (Silvex)	1	100												
Vinyl Chloride	0.2	20	1	U	1	U	1	U	1	U	1	U	1	U
WTPH (mg/Kg)														
Diesel Range (>C12 Thru C24)	NA	NA	2580		104		1310		19900		833		2010	
Gasoline Range (C7 Thru C12)	NA	NA	40	U	32	U			1220		28	U	31	U
Heavy Oil Range (>C24)	NA	NA	3540		244		2160		20800		3160		6250	
Conventionals														
Corrosivity (pH)	(2)	(2)	7.6		8		7.8		8		7.1		7.8	
Cyanide Reactivity (mg/Kg)	(2)	(2)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Flash Point (ºF)	(2)	(2)	160	>	160	>		TIA	160	>	160	>	160	>
Sulfide Reactivity (mg/Kg)	(2)	(2)	50	U	50	U	50	U	50	U	340		110	

DW = Dangerous Waste

EHW = Extremely Hazardous Waste

NA = Not Available

(1) Chapter 173-303 WAC, Washington State Dangerous Waste Regulations, as amended November 1995.

(2) Narrative description in WAC 173-303-090.

- Striplin Environmental Associates Duwamish Diagonal Bioassay Review, February 11, 1997.
- King County Environmental Laboratory Phase II Bioassay Review, December 10, 1996 and January 9, 1997.

Complete laboratory QA1 reports including definitions of the qualifiers used, are included as **Appendix L**. Qualified data indicate higher uncertainty (higher variability) in reported results. Qualified results should be used with caution for decision-making purposes. Modifications to laboratory qualifiers included: 1) laboratory qualifiers reported as <MDL were converted to a U qualifier (undetected); and 2) laboratory qualifiers reported as <RDL were converted to a J qualifier (tentatively detected).

The chemical data were reviewed for the following parameters, where applicable: 1) completeness, 2) methods, 3) target list, 4) detection limits, 5) holding times and conditions, 6) method blanks, 7) standard reference materials, 8) replicates, 9) units and significant figures, 10) matrix spikes, and 11) surrogates. The bioassay data were reviewed against PSEP protocols, and tables and narrative sections were evaluated for accuracy against bench sheet data.

Overall, no chemical data were rejected as unusable for the Cleanup Study Report, although some data were qualified. Conversely, Phase 1 bioassay data were rejected for regulatory purposes based on Ecology review (Michelsen 1995). Phase 1 bioassay data are not included in this report. Major issues identified in the QA1 reviews are presented below.

4.3.1 QA Review of Phase 1 Data

4.3.1.1 Particle Size Distribution (PSD)

- Five triplicate samples were analyzed to evaluate precision. The percent Relative Standard Deviation (% RSD) for a number of phi sizes were outside the acceptable QC range. Poor precision was observed throughout the phi size range without a consistent pattern; therefore, high or low bias in reported results could not be determined. All PSD data were qualified as estimated (E).

4.3.1.2 Acid Volatile Sulfides

- Seven triplicate samples were analyzed to evaluate precision. The % RSD values were within the acceptable QC range for five of the seven triplicate samples. In many cases, the sample triplicates were analyzed from two different sample containers collected for the same sample. It appears that some of the variability may be associated with sample containers and may not be entirely due to analytical performance. All acid volatile sulfides data were qualified as estimated.

4.3.1.3 Metals

- In general, reported Relative Percent Differences (RPD) for replicate samples are within the acceptable QC range and have not resulted in data qualification. Data associated with replicate RPD of greater than 20 percent were qualified as estimated. The high RPD values for arsenic, copper, and lead in Samples 4378-3 to 4378-10 and 4378-12 to 4378-17 can be attributed to the observed difficulty in obtaining a homogeneous subsample from these samples, and indicate higher uncertainty (higher variability) in reported results.

- Data associated with matrix spike recoveries outside the acceptable QC range were qualified as estimated with either the G (low recovery) or L (high recovery) flag. Poor spike recovery values were reported for copper (54 percent), lead (137 percent), antimony (25 percent, 20 percent, 33 percent, and 37 percent), and zinc (0 percent and 69 percent). Zinc results associated with a spike recovery value of 0 percent were qualified as X (very low recovery).

4.3.1.4 Organics

- Extracts used to determine chlorobenzenes and related compounds by ion trap GC/MS were analyzed beyond the SAP specified holding time. All chlorobenzene and related compound results were qualified as estimated. The detection limit for hexachlorobenzene in Samples 4288-12 and 4288-13 exceeded the SQS due to low levels of TOC in the samples.

- Di-n-butyl phthalate, butyl benzyl phthalate, bis (2-ethylhexyl) phthalate, 1,2-dichloro-benzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene were detected in at least one method blank. Associated data were qualified with a B (contamination reported in the blank).

- Elevated detection limits were reported for butyltin isomers in samples 4288-4, -11, -24, -30, and -31 due to dilutions necessary to control for matrix interferences and chromatography problems.

- Low surrogate recovery was reported for the pesticide analysis for Sample 4378-6. All pesticide results for this sample were qualified as estimated.

- Isolated instances of replicate RPD values outside the acceptable Quality Control (QC) range were reported for BNA analyses. Results for acenapthene, 4-nitroanaline, and benzoic acid in affected samples were qualified as estimated.

4.3.1.5 Bioassays

- Ecology reviewed the reported results for the three sediment bioassays and determined that the data sets were unusable for regulatory purposes (Michelsen 1995). Data for two of three tests were considered invalid, and only the amphipod bioassay data appeared unaffected.

- Three QC issues were identified that affected the usability of results: 1) results of the positive control tests for the echinoderm larval bioassay showed that the larvae survived well above the normal control range and did not show a dose-response pattern when exposed to the control toxicant; 2) the initial starting weight of all of the polychaete Neanthes worms was lower than recommended by PSEP protocols resulting in low growth rates that did not meet SMS performance standards; and 3) numerous water quality exceedances were noted for dissolved oxygen, pH, and salinity during the above testing.

- Because two test results were considered invalid, the Phase 1 bioassay data are unusable for comparison to SMS biological criteria and are not considered further in this report.

4.3.2 QA Review of Phase 1.5 Data

4.3.2.1 Metals

- The Standard Reference Material (SRM) recovery value for antimony was less than 80 percent (24 percent) and the matrix spike recovery value was less than 75 percent (28 percent). All sample results for antimony were qualified as estimated (G, low bias).

- Matrix spike recovery values were outside the accepted QC range (75 percent to 125 percent) for sodium (57 percent) and aluminum (531 percent). Associated sample results were qualified as estimated (G, low bias; L, high bias).

- Laboratory duplicate RPD values outside the accepted QC range (>20 percent) were reported for aluminum (38 percent) and arsenic (38 percent). Associated sample results were qualified as estimated (E).

4.3.2.2 Organics

- Chlorobenzene surrogate recovery values for all samples were low (0 to 32 percent). Results for sample L7279-1 were qualified as very biased (X). Results for the remaining samples were qualified as estimated (G, low bias).

- The SRM recovery value for several BNA compounds were outside the accepted QC range of 80 to 120 percent (55 to 72 percent and 143 percent). All sample results were qualified as estimated (G, low bias; L, high bias). Matrix spike results for 1,3-, 1,4-, and 1,2-dichlorobenzene were also outside the accepted QC range of 75 to 125 percent (41 to 46 percent). Results for all samples were qualified as estimated (G, low bias).

- BNA matrix spike recovery values for several compounds were outside the accepted QC range of 75 to 125 percent (0 to 47 percent and 170 to 172 percent). All sample results were qualified as estimated (X, very biased; G, low bias; L high bias).

- A laboratory duplicate RPD value exceeding the QC limit of 100 percent (115.9 percent) was reported for Aroclor 1260, possibly due to inadvertent spiking of the duplicate sample. All sample results for Aroclor 1260 were qualified as estimated (E).

4.3.3 QA Review of Phase 2 Surface Sediment Data

4.3.3.1 Metals

- The 28-day mercury holding time was exceeded for Samples 9446-1 through 9446-2 (Carr Inlet reference samples). Associated data were qualified with the H flag.

- The SRM recovery value for antimony was less than 80 percent (33 percent) and the matrix spike recovery value was less than 75 percent (27 percent). All sample results for antimony were qualified as estimated (G, low bias). The SRM recovery value for cadmium was greater than 120 percent (125 percent). All sample results for cadmium were qualified as estimated (L, high bias).

- Matrix spike recovery values for aluminum, antimony, iron, and silver in Samples 8542-8 through 8542-10 were outside the accepted QC range of 75 percent to 125 percent (410 percent, 27 percent, 67 percent, and 30 percent, respectively). Matrix spike recovery values for aluminum, antimony, and iron in Samples 9443-1 through 9443-8 were outside the accepted QC range 75 percent to 125 percent (163 percent, 25 percent, and 72 percent, respectively). Matrix spike recovery values for aluminum, antimony, and iron in Samples 9446-1 through 9446-2 were outside the accepted QC range 75 percent to 125 percent (60 percent, 37 percent, and 67 percent, respectively). Associated sample results were qualified as estimated (G, low bias; L, high bias).

4.3.3.2 Organics

- Bis (2-ethylhexyl) phthalate and butyl benzyl phthalate were detected in the method blank associated with Samples 8542-9 through 8542-10. Associated data were qualified with a B (contamination reported in the blank).

- The SRM recovery values for several BNA compounds were outside the accepted QC range of 80 percent to 120 percent (13 percent to 72 percent). All sample results for these compounds were qualified as estimated (G, low bias).

- The PCB SRM recovery value was less than 80 percent (60 percent) for Aroclor 1254. Associated sample data were qualified as estimated (G, low bias).

- Matrix spike results for 1,3-, 1,4-, and 1,2-dichlorobenzene, were outside the accepted QC range of 75 percent to 125 percent (32 percent to 38 percent). Results for Samples 8542-8, 8542-9, and 9443-1 through 9443-8 were qualified as estimated (G, low bias).

- Matrix spike results for numerous BNA compounds in Samples 8542-8 through 8542-10, 9446-1, 9446-2, and 9443-1 through 9443-8, were outside the accepted QC range of 75 percent to 125 percent (0 percent to 48 percent). Results for these compounds were qualified as estimated (X, very biased; or G, low bias).

- Laboratory RPD values for 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,2,4-trichlorobenzene, and hexachlorobenzene were greater than the QC limit of 100 percent (133 percent to 200 percent) for the duplicate Samples 8542-8 through 8542-10. Associated sample data for these compounds were qualified as estimated (E).

4.3.4 QA Review of Phase 2 Subsurface Data

4.3.4.1 Metals

- The 28-day sample holding time for mercury was exceeded by seven days for Samples 8542-32 through 8542-39. Mercury analytical results for these samples were qualified with an XHT flag indicating an exceedance of holding time. The 28-day mercury holding time was exceeded for Samples 9142-1 through 9142-3. Associated data were qualified with the H flag.

- The SRM recovery value for antimony was less than 80 percent (33 percent and 33 percent), and the matrix spike recovery values were less than 75 percent (35 percent and 27 percent). All sample results for antimony were qualified as estimated (G, low bias).

- Matrix spike recovery values were outside the accepted QC range of 75 percent to 125 percent for mercury (138 percent), sodium (53 percent), and aluminum (174 percent). Associated sample results were qualified as estimated (G, low bias; L, high bias). Matrix spike recovery values for antimony, silver, sodium, and mercury in Samples 9142-1 through 9142-3 were outside the accepted QC range of 75 percent to 125 percent (22 percent, 60 percent, 66 percent, and -44 percent, respectively). Associated sample results were qualified as estimated (X, very biased; G, low bias).

- Laboratory duplicate RPD values exceeding the QC limit of 20 percent were reported for copper (29 percent), lead (32 percent), and mercury (64 percent) for samples 8542-32 through 8542-39. Associated sample results were qualified as estimated (E).

4.3.4.2 Organics

- Bis (2-ethylhexyl) phthalate was detected in the method blank associated with Samples 8542-12 through 8542-18 and 8542-35 through 8542-38. Di-n-butyl phthalate was detected in the method blank associated with Samples 9142-1 through 9142-3. Associated data were qualified with a B (contamination reported in the blank).

- Chlorobenzene surrogate recovery values for all samples were low (2 percent to 32 percent). Results for Samples 8542-15, 8542-16, and 8542-30 were qualified as very biased (X). Results for the remaining samples were qualified as estimated (G, low bias). Chlorobenzene surrogate recovery values were less than the 50 percent QC limit (25 percent to 32 percent) in Samples 9142-1 through 9142-3. All chlorobenzene results in these samples were qualified as estimated (G, low bias).

- BNA surrogate recovery values for several samples were less than 50 percent (15.5 percent to 49.5 percent). Results for these samples were qualified as estimated (G, low bias).

- The SRM recovery values for several BNA compounds were outside the accepted QC range of 80 percent to 120 percent (14 percent to 67 percent). All sample results for these compounds were qualified as estimated (G, low bias).

- Matrix spike results for 1,3-, 1,4-, and 1,2-dichlorobenzene, and 1,2,4-trichlorobenzene were outside the accepted QC range of 75 percent to 125 percent (29 percent to 49 percent). Results for several samples were qualified as estimated (G, low bias).

- Matrix spike results for numerous BNA compounds in Samples 8542-19, 8542-20, 8542-26, and 8542-31 through 8542-34, and 9142-1 through 9142-3, were outside the accepted QC range of 75 percent to 125 percent (0 percent to 50 percent). Results for these compounds were qualified as estimated (X, very biased; G, low bias; or L, high bias).

- Matrix spike results for PCB Aroclor 1260 were outside the accepted QC range of 50 percent to 150 percent (36 percent and 43 percent, and 159 percent). Results for Samples 8542-12 through 8542-27, and 8542-29 through 8542-39, and 9142-1 through 9142-3, were qualified as estimated (G, low bias; or L, high bias).

4.3.5 QA Review of Phase 2 Bioassay Data

Two acute effects tests (10-day amphipod and echinoderm larval) and one chronic effects test (20-day *Neanthes* growth) were performed on seven test sediments (DUD200 through DUD206), two control sediments (Control A and Control B), and two reference sediments (P9446-1 and P9446-2). MEC Analytical Systems, Inc. (MEC) of Carlsbad, California performed the bioassays. Laboratory methods, data quality issues, and test results are presented in a final report to King County (MEC 1996; **Appendix L**). The laboratory used methods described in MEC bioassay protocols and PSEP (1995). MEC and KCDNR conducted Quality Assurance reviews of the Phase 2 bioassay data (**Appendix L**).

Deviations from the protocol and/or SAP include:

Juvenile Polychaete

- Water quality measurements were taken for each sample every third day, as specified in PSEP, instead of every day as specified in the SAP.

- Reference sediment growth rates were less than the SMS growth criterion of 80 percent of control growth.

Amphipod

- Sample preparation, sample identification, or other error occurred with the positive control test.

Echinoderm Larval

- The first control did not meet the protocol specification so new animals were received and testing was repeated. Sediment samples were held four days past the 14-day holding time at the start of the second test.

- The positive control sample was not stored and handled correctly/properly.

4.4 SURFACE SEDIMENT CHEMISTRY RESULTS

Appendix A includes surface sediment (i.e., 0 to 10 cm depth) chemistry results for conventionals and SMS chemicals. Concentrations for SMS chemicals are compared to SMS criteria defined in WAC 173-204, which provides sediment quality criteria for the following effects levels:

- ***SQS criteria:*** Establishes a sediment quality that will result in no adverse effects on biological resources (WAC 173-204-320).
- ***CSL criteria:*** Establishes minor adverse effects levels, above which station clusters of potential concern are defined as cleanup sites (WAC 173-204-530), and also establishes minimum cleanup levels (MCULs) to be used in evaluation of cleanup alternatives (WAC 173-204-560).

Because SMS criteria for most nonionizable organic chemicals are listed in units of mg/kg organic carbon (OC), laboratory chemical data which were typically expressed as ug/kg dry weight (ppb DW) were first changed to mg/kg dry weight (ppm DW) and then converted to mg/kg OC, using the following equation:

$$\text{mg / kg OC} = \frac{\text{mg / kg DW}}{\text{TOC}}$$

where TOC = percent total organic carbon expressed as the decimal equivalent.

This conversion was calculated for each station, based on station-specific TOC data. For original DW concentrations of organic chemicals, refer to **Appendix A**.

Ecology has indicated that for low TOC sediments (e.g., 0.1 to 0.2 percent), comparison of nonionizable organic concentrations to OC-normalized SMS criteria may not be appropriate since the low TOC would not control chemical bioavailability. For these conditions, Ecology may allow a comparison of dry weight concentrations to dry weight Apparent Effects Threshold (AET) values on a site-specific basis to evaluate sediment toxicity (Michelsen 1992). AET values have been developed for 64 organic and inorganic chemicals based on the observed relationships between biological effects and chemical concentrations (PSEP 1988). Therefore, in addition to the SMS criteria comparison presented in **Appendix A**, an additional comparison to the lowest AET (LAET) values of four biological indicators is presented in the second set of tables in **Appendix A**, for stations with TOC concentrations <0.2 percent. Comparison to LAET values were used as an SQS surrogate, while comparison to the second-lowest AET (2LAET) values was used as a CSL surrogate.

For this Cleanup Study Report, the chemical summing method for chemical groups (i.e., total LPAHs, total HPAHs, total benzofluoranthenes, and total PCBs) followed SMS procedures, which include: 1) using the highest detection limit reported for an individual chemical in a group when all chemicals are undetected; and 2) summing only the detected values when one or more chemicals in a group are detected.

Preliminary review of surface sediment chemistry data indicated that three distinct contamination areas are apparent for the site. The area adjacent to the Duwamish/Diagonal outfalls are characterized by elevated levels of several contaminants predominated by bis (2-ethylhexyl) phthalate. This area is referred to as the North Inshore Area. The area offshore of the cement plant dock and old treatment plant outfall is characterized by elevated levels of several chemicals dominated by PCBs, phthalates, and chlorinated benzenes. This area is referred to as the South Inshore Area. The third area is the dredged river channel located at the offshore edge of the two inshore areas. This entire channel area is dominated by PCB exceedances, but a few other chemicals also have exceedances.

4.4.1 Conventionals

4.4.1.1 Total Organic Carbon

Surface sediment TOC concentrations ranged from 0.08 to 9.42 percent; for comparison, a range of 0.5 to 3 percent is typical for Puget Sound marine sediments (Michelsen 1992). **Figure 4-2** illustrates the spatial distribution of TOC values. Maximum concentrations were reported near the former City treatment plant outfall and south of the Duwamish Outfall. The following Duwamish/Diagonal surface sediment stations are characterized by low TOC concentrations (<0.2 percent) and are compared to AET values in addition to SMS criteria:

- DUD013
- DUD015

Both of these stations are located in a sandy near shore area adjacent to the Diagonal Avenue South outfall, in the South Study Area.

4.4.1.2 Particle Size Distribution

Particle size distribution data are reported in **Appendix A** as percentages of gravel, sand, silt, and clay. In addition, the distribution of percent fines (silt + clay) is illustrated in **Figure 4-3** to indicate areas of deposition and scouring. Generally, the coarsest sediments identified in the Study Area (<20 percent fines) were located in the intertidal stations. Finer sediments (> 60 percent fines) were located closer to the dredged river channel stations where sediment deposition appears more pronounced.

4.4.1.3 Salinity

Salinity was measured in twelve surface sediment samples collected during Phase 1. Salinity concentrations ranged from 21 to 27 parts per thousand. In comparison, Pre-Phase 1-sediment salinity concentrations ranged from 21 parts per thousand (intertidal sediment) to 33 parts per thousand (deep-water sediment). The SMS defines sediments with pore water concentrations greater than 25 parts per thousand salinity as “marine sediments,” while those with pore water concentrations between 0.5 and 25 parts per thousand salinity are defined as “low salinity sediments.” SMS “marine” sediment quality criteria are used to evaluate site data, including “low salinity sediments.” “Low salinity sediment” criteria are not available. In addition, salinity data were used to select appropriate bioassay test organisms and test conditions. Salinity data are reported in **Appendix A.**

4.4.2 Inorganics

Detected inorganic chemicals exceeding SMS criteria in surface sediment samples for the North and South Inshore Areas and dredged channel are summarized in **Tables 4.3, 4.4, and 4.5** respectively. Methyl mercury represented a small fraction (0.10 to 1.4 percent) of the total mercury content for Phase 1 samples (**Appendix A**). SQS/CSL inorganic chemical exceedances were dominated by mercury and zinc in the North Inshore Area, by mercury in the South Inshore Area and by mercury in the channel area.

Of the three SQS zinc exceedances reported for the North Inshore Area, two of these were associated with stations located away from the outfalls. Therefore, zinc does not appear to represent a contaminant of concern due to outfall discharges. This information tends to contradict the recontamination modeling results presented in **Section 3.4.1**, which indicated that zinc would have the greatest potential to recontaminate the Study Area following cleanup actions.

4.4.3 Organics

Detected organic chemicals exceeding SMS/AET criteria in surface sediment samples for the North and South Inshore Areas and dredged channel area are included in **Tables 4.3 and 4.4**, **and 4.5** respectively. SQS/CSL organic chemical exceedances were dominated by PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate in all three areas.

Table 4.3 SURFACE SEDIMENT EXCEEDANCES OF SMS CRITERIA OR AET VALUES [a] NORTH INSHORE AREA

Chemical	Stations Exceeding SQS Only[b]	Stations Exceeding CSL[b]
Mercury	DUD016 DUD021 DUD029	DUD004
Zinc	DUD005 DUD028	--
1,2-Dichlorobenzene	--	DR008
1,4-Dichlorobenzene	--	DR007
Total HPAH	DR006 DR007 DR059	DR008 DR009
Total LPAH	DR007 DR008	DR009
Total PCBs	DUD001 DUD023 DUD200 DUD004 DUD024 DUD201 DUD007 DUD029 DUD202 DUD016 DUD030 DUD204 DUD020 DUD031 DR007 DUD021 DUD042 DR059 DUD022 DUD043	DUD028 DR006 DR008 DR009
bis(2-ethylhexyl)phthalate	DUD008 DUD016 DUD029 DUD030 DUD031 DUD200 DUD201	DUD001 DUD017 DUD042 DUD002 DUD018 DUD043 DUD003 DUD019 DUD202 DUD004 DUD020 DUD204 DUD005 DUD021 DR007 DUD006 DUD022 DR008 DUD007 DUD023 DR009 DUD009 DUD024 DR059 DUD016(rep) DUD028
Butyl benzyl phthalate	DUD001 DUD016 DUD042 DUD002 DUD017 DUD043 DUD003 DUD018 DUD200 DUD004 DUD019 DUD202 DUD005 DUD021 DUD204 DUD007 DUD022 DR006 DUD008 DUD024 DR059 DUD009	DR007 DR008 DR009
Phenol	DUD020	--
4-Methylphenol	--	DUD200 DUD204

Footnotes:
[a] Exceedances based on detected chemicals only
[b] SQS/CSL Exceedances are reported for stations with TOC concentrations > 0.2

Other Notes:
SMS: Sediment Management Standards, WAC 173-204
SQS: Sediment Quality Standards, WAC 173-204-320
CSL: Cleanup Screening Levels, WAC 173-204-520
LAET: Lowest Apparent Effects Threshold, PSEP 1988

Table 4.4 SURFACE SEDIMENT EXCEEDANCES OF SMS CRITERIA OR AET VALUES[a] SOUTH INSHORE AREA

Chemical	Stations Exceeding SQS Only[b]	Stations Exceeding CSL[b]
Cadmium	DUD012	DUD027
Chromium	--	DUD027
Lead	--	DUD027
Mercury	DUD026	DUD012 DUD027
Silver	--	DUD012 DUD027
Zinc	DUD027	--
Total HPAHs	DR011	--
Total PCBs	DUD010 DUD025 DUD205 DUD016 DUD037 DUD209	DUD012 DUD027 DUD026 DR011
1,2,4-Trichlorobenzene	DUD012	DUD027
1,2-Dichlorobenzene	--	DUD012 DUD027
1,4-Dichlorobenzene	DUD015	DUD027
2-Methylnaphthalene	DUD027	--
4-Methylphenol	--	DUD205 DUD207
bis(2-ethylhexyl)phthalate	DUD016 DUD036 DUD037	DUD010 DUD025 DUD205 DUD012 DUD026 DR010 DUD014 DUD027 DR011 DUD015
Butyl benzyl phthalate	DUD010 DUD025 DR010 DUD012 DUD205 DR011 DUD014	DUD026

Footnotes:
[a] Exceedances based on detected chemicals only
[b] SQS/CSL Exceedances are reported for stations with TOC concentrations >0.2 percent

Other Notes:
SMS: Sediment Management Standards, WAC 173-204
SQS: Sediment Quality Standards, WAC 173-204-320
CSL: Cleanup Screening Levels, WAC 173-204-520
LAET: Lowest Apparent Effects Threshold, PSEP 1988

Table 4.5 SURFACE SEDIMENT EXCEEDANCES OF SMS CRITERIA OR AET VALUES DREDGED CHANNEL AREA

Chemical	Stations Exceeding SQS Only	Stations Exceeding CSL
Arsenic	--	DUD032
Mercury	DUD035 DUD038	DUD032
Zinc	DUD032	
Total PCBs	DUD038 DUD040 DUD045 DUD039 DUD041 DR082	DUD032 DR081 DUD044
Bis (2-ethylhexyl) Phthalate	DUD033 DUD036 DUD045 DUD034 DUD038 DR080 DUD035 DUD040	DUD032 DR081 DUD044 DR082
Butyl Benzyl Phthalate	DUD032 DUD040 DR080 DUD038 DUD044 DR082 DUD039 DUD045	--

Hexachlorobenzene	DUD039 DUD044	--

For those surface sediment stations exhibiting TOC concentrations <0.2 percent (i.e., DUD013 and DUD015), no chemicals were detected above the corresponding LAET. These stations are located adjacent to the Diagonal Avenue South outfall, in the South Inshore Area.

Although there are no SMS/AET criteria established for tributyltin (TBT), all Phase 1 surface sediment samples were analyzed for TBT due to its high toxicity and due to concentrations found in other studies. Phase 1 results indicate that TBT concentrations were highest offshore and away from the outfalls (**Appendix M**).

4.5 SUBSURFACE SEDIMENT RESULTS

Appendix A includes subsurface sediment chemistry data for conventionals and SMS chemicals. Similar to the surface sediment presentation, concentrations of SMS chemicals are compared to SMS criteria. If TOC values are less than 0.2 percent, SMS chemicals are also compared to AET values in the second set of tables in **Appendix A.**

During Phase 1, two cores (DUD006, DUD020) were collected adjacent to the Duwamish/Diagonal outfalls. The cores were sectioned into 15-cm segments, which extended down to 150 cm (5 feet) at DUD006 and down to 90 cm (3 feet) at DUD020. Core results were discussed in the Phase 1 Results Summary (**Appendix M**), which indicated the cores were collected from an area of sediment that appears to have been disturbed (mixed) during installation of the Duwamish siphon. Exceedances of SMS criteria for these core samples are included in **Appendix A**. Results indicated that bis (2-ethylhexyl) phthalate exceeded CSL criteria in every core segment collected at DUD006; therefore, the bottom depth of contamination was not established near the outfall.

During Phase 2, fourteen cores (DUD250 to DUD258, DUD260 to DUD262, and DUD027 and DUD206) were collected throughout the study area and sectioned into three segments (0 to 90 cm [0 to 3 feet]; 90 to 180 cm [3 to 6 feet]; 180 to 270 cm [6 to 9 feet]). The top section (0 to 90 cm) was analyzed for all SMS parameters. The middle section (90 to 180 cm) of all but four cores was analyzed for all SMS parameters, while this section from the remaining four cores was archived. A lower section (180 to 270 cm) of each core was archived. Upon analysis and preliminary interpretation of the core data, some of the archived sections were analyzed for PCBs and conventionals. The following discussion focuses on the vertical extent of contamination at the Phase 2 locations, since this provides more representative data for undisturbed core segments.

4.5.1 Conventionals

4.5.1.1 Total Organic Carbon

TOC concentrations ranged between 0.07 to 5.25 percent in the upper section (0 to 90 cm), and between 0.03 to 6.45 percent in the deeper core sections (90 to 180 cm).

The following Duwamish/Diagonal core sections are characterized by low TOC concentrations (<0.2 percent) and were compared to AET values in addition to SMS criteria:

- DUD251 (90 to 180 cm), (180 to 270 cm)
- DUD252 (0 to 90 cm), (90 to 180 cm), (180 to 270 cm)
- DUD206 (0 to 90 cm)
- DUD257 (180 to 270 cm)
- DUD258 (180-270 cm)

Core Stations DUD251, DUD252, DUD257, and DUD258 were located in the North Inshore Area, while Core Station DUD206 was located in the South Inshore Area, in the intertidal area behind the E-shaped pier.

4.5.1.2 Particle Size Distribution

Particle size distribution in core segments was highly variable, possibly due to historical dredging operations for the outfall siphon pipe and for the E-shaped pier area. **Figure 4-4** illustrates the percent sand reported for each core segment. Unlike results reported near the Norfolk CSO located upstream (where sand increased to 93 to 96 percent at core depths exceeding three feet), there was no observable trend with depth at the Study Area.

4.5.2 Inorganics

Inorganic chemicals exceeding SMS criteria for core samples collected from the North and South Inshore Study Areas are summarized in **Table 4.6** and **Table 4.7**, respectively.

Table 4.6 SEDIMENT CORE EXCEEDANCES OF SMS CRITERIA OR AET VALUES[a]
NORTH INSHORE AREA

Chemical	Station Cores Exceeding SQS Only[b]		Station Cores Exceeding CSL[b]	
	(0 to 90 cm)	(90 to 180 cm)	(0 to 90 cm)	(90 to 180 cm)
Cadmium	DUD020	DUD254 DUD255	--	--
Copper	--	--	DUD006	--
Lead	DUD254	DR008	DUD006 DUD020	DUD006 DUD254
Mercury	DUD251 DUD256 DUD258	DUD253	DUD006 DUD020 DUD254 DUD255 DR008	DUD006 DUD254 DUD255 DR008
Silver	--	--	--	DUD255
Zinc	DUD006 DUD020 DR008	DUD254	--	--

Chemical	Station Cores Exceeding SQS Only[b]		Station Cores Exceeding CSL[b]	
	(0 to 90 cm)	(90 to 180 cm)	(0 to 90 cm)	(90 to 180 cm)
Total HPAHs	DUD006 DR008	DUD006 DR008	--	--
Total LPAHs	DUD006 DR008	--	--	DUD006
Total PCBs	DUD253 DUD254* DUD256 DUD257 DUD258	DUD251[c] DUD255	DUD006 DUD020 DUD250 DUD251 DUD252 DUD255 DR008	DUD006 DUD253* DUD254 DUD256 DUD258 DR008
1,4-Dichlorobenzene	--	DUD006	DUD006 DUD254 DR008	DUD254 DR008
1,2-Dichlorobenzene	--	--	--	DUD006 DR008
bis(2-ethylhexyl)phthalate	DUD253	DUD253 DUD256	DUD006 DUD020 DUD250 DUD251 DUD254 DUD255 DUD256 DUD258 DR008	DUD006 DUD254 DR008
Butyl benzyl phthalate	DUD020 DUD250 DUD251 DUD254 DUD256 DUD258	DUD006 DUD254	DUD006 DR008	DR008
Phenol	DUD006			

Footnotes:
[a] Exceedances based on detected chemicals only
[b]SQS/CSL Exceedances are reported for stations with TOC concentrations >0.2 percent.
[c]LAET/2LAET Exceedances are reported for stations with TOC concentrations <0.2 percent.
* Also exceeded SQS or CSL in 180 to 270 cm core segment.

Other Notes:
(0 to 90) Core section in centimeters.
SMS: Sediment Management Standards, WAC 173-204
CSL: Cleanup Screening Levels, WAC 173-204-520
SQS: Sediment Quality Standards, WAC 173-204-320
LAET: Lowest Apparent Effects Threshold, PSEP 1988

Table 4.7 SEDIMENT CORE EXCEEDANCES OF SMS CRITERIA OR AET VALUES [a]
SOUTH INSHORE AREA

Chemical	Station Cores Exceeding SQS Only[b]		Station Cores Exceeding CSL[b]	
	(0 to 90 cm)	(90 to 180 cm)	(0 to 90 cm)	(90 to 180 cm)
Mercury	--	--	DUD027 DUD262	DUD027 DUD261
Cadmium	--	DUD027	DUD027	DUD261
Chromium	--	--	DUD027	--
Lead	--	--	DUD027	--
Silver	--	--	DUD027 DUD262	DUD027 DUD261 DUD262
Zinc	--	DUD261	DUD027	--
Total PCBs	--	DUD260 DUD262	DUD027 DUD260 DUD261 DUD262	DUD027 DUD261
1,2-Dichlorobenzene	--	--	DUD262	DUD027 DUD261
1,4-Dichlorobenzene	DUD027 DUD262	DUD027 DUD262	--	--
1,2,4-Trichlorobenzene	DUD027	DUD261	--	DUD027
bis(2-ethylhexyl)phthalate	DUD261	--	DUD027 DUD260 DUD262	DUD027 DUD261
Butyl benzyl phthalate	DUD260	--	--	--

Footnotes:
[a] Exceedances based on detected chemicals only
[b]SQS/CSL Exceedances are reported for stations with TOC concentrations >0.2 percent.
(0 to 90) Core section in centimeters.
SQS: Sediment Quality Standards, WAC 173-204-320
SMS: Sediment Management Standards, WAC 173-204
CSL: Cleanup Screening Levels, WAC 173-204-520

SQS/CSL inorganic chemical exceedances were dominated by mercury in the North Inshore Area, and by mercury, cadmium, and silver in the South Inshore Area. The vertical extent of contamination for chemicals of concern is discussed further in **Chapter 5.0**.

4.5.3 Organics

Organic chemicals exceeding SMS/AET criteria for core samples collected from the North and South Inshore Areas are summarized in **Table 4.6** and **Table 4.7**, respectively.

SQS/CSL organic chemical exceedances were dominated by PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate in the North Inshore Area, and by PCBs, 1,2-dichlorobenzene, 1,2,4-trichlorobenzene, and bis (2-ethylhexyl) phthalate in the South Inshore Area. The vertical extent of contamination for chemicals of concern is discussed further in **Chapter 5.0**.

4.6 SURFACE SEDIMENT BIOASSAY RESULTS

Under the SMS rule, the potential for sediment to cause adverse biological effects is defined by chemical criteria. Biological testing is routinely used to confirm chemical designation of sediments (Ecology 1996). Three of the biological tests specified by the SMS rule were used in this study: 1) Ten-Day Amphipod; 2) Twenty-Day Juvenile Polychaete; and 3) Echinoderm Embryo. The amphipod and echinoderm bioassays were selected to identify acute effects based on mortality and effective mortality (combined mortality and abnormality) endpoints, respectively. The juvenile polychaete bioassay was selected to evaluate chronic effects based on a growth rate endpoint. The above test species were selected after a review of test sediment and organism characteristics, including sediment grain size and salinity, and organism availability and spawning condition.

As discussed in **Section 4.3** (QA/QC Results), Phase 1 bioassay results were rejected due to testing performance failures and are not considered further. Phase 2 bioassay results and SMS interpretation are summarized in **Table 4.8** and discussed below. Some assumptions relative to the evaluation of the Phase 2 bioassay data included:

- Sample DUD206 (8 percent sand) was compared with Control B, collected from Whidbey Island, in all three bioassays. Sediments from this area have been tested for grain size by the USACE and typically contain approximately 5 percent sand.

- Reference Samples P9446-1 and P9446-2 failed SMS performance criteria for the juvenile polychaete test. The reference mean growth rate endpoint (GRE) must be at least 80 percent of the control mean. The mean GRE for P9446-1 was 0.48 mg/individual/day, and the mean GRE for P9446-2 was 0.60 mg/individual/day. Reference Sample P9446-2 failed the performance criteria by only 0.02 mg/individual/day. Because of this slight exceedance coupled with low standard deviation among replicates, reference Sample P9446-2 was approved by Ecology for comparisons with DUD200 through DUD205.

- Reference sediment Sample P9446-1 was not used for any test/reference comparisons because its grain size was a poor match for the test sediments.

Additional bioassay data are located in **Appendix N** (Sediment Bioassay Results) and **Appendix L** (Laboratory QA1 Reports – Chemistry and Bioassay).

4.6.1 Amphipod Bioassay

The amphipod test using *Rhepoxynius abronius* was conducted for seven test sediments, two reference sediments, and two control sediments. The reference and control sediments met the applicable SMS performance criteria for the amphipod test. SMS interpretive results were determined using the following SMS biological effects criteria:

- Fails SQS (WAC 173-204-320). The test sediment has a significantly higher ($P \leq 0.05$) mean mortality than the reference sediment, and the test sediment mortality exceeds 25 percent.

- Fails CSL (WAC 173-204-520). The test sediment has a significantly higher ($P \leq 0.05$) mean mortality than the reference sediment, and the test sediment mean mortality is 30 percent greater than the reference sediment.

Amphipod bioassay results are summarized in **Table 4.8**. Station DUD204 was the only station to exceed SMS biological criteria.

4.6.2 Echinoderm Larval Bioassay

The sediment larval test using the echinoderm *Dendraster excentricus* was conducted for seven test sediments, two reference sediments, two control sediments, and one seawater control. The seawater control met the applicable SMS performance criteria for the echinoderm test. SMS interpretive results were determined using the following SMS biological effects criteria:

- Fails SQS (WAC 173-204-320). The test sediment has a combined abnormality and mortality that is more than 15 percent greater than the reference sediment, and the difference is statistically significant ($P \leq 0.10$).

- Fails CSL (WAC 173-204-520). The test sediment has a combined abnormality and mortality that is more than 30 percent greater than the reference sediment, and the difference is statistically significant ($P \leq 0.10$).

Echinoderm bioassay results are summarized in **Table 4.8**. Station DUD206 was the only station to exceed SMS biological criteria.

Table 4.8 BIOASSAY RESULTS AND SMS INTERPRETATION

		Amphipod Bioassay		20-Day Juvenile Polychaete		Echinoderm Larval	
Station ID	Reference Match	%Mortality (Mean)	SMS Status	Growth Rate (Mean)	SMS Status	%Mort./Abn (Mean)	SMS Status
Test Sediment	P9446-2(Ref)						
DUD200	P9446-2(Ref)	13	Pass	0.60	Pass	32.46	Pass
DUD201	P9446-2(Ref)	21	Pass	0.55	Pass	34.55	Pass
DUD202	P9446-2(Ref)	18	Pass	0.62	Pass	34.97	Pass
DUD203	P9446-2(Ref)	22	Pass	0.59	Pass	32.83	Pass
DUD204	P9446-2(Ref)	26*	>SQS	0.51	Pass	16.63	Pass
DUD205	P9446-2(Ref)	19	Pass	0.54	Pass	15.88	Pass
DUD206	Control B	4	Pass	0.52*	>SQS	34.17*	>SQS
Controls:							
P9446-1(Ref)		6[b]		0.48[d]		27.06[f]	
P9446-2(Ref)		8[b]		0.60[d]		29.04	
Control A		3[a]		0.82[c]		30.96	
Control B		1[a]		0.77[c]		15.24	
Seawater						11.82[e]	

Footnotes:
[a] Control sample passes performance criteria of <10% mortality

[b] Reference sample passes performances criteria of <25% mortality
[c] Control sample passes performance criteria of <10% mortality and mean individual growth rate of ≥0.72 mg/individual/day
[d] Reference sample fails performance criteria because reference sediment mean individual growth rate is <80% of the mean individual growth rate in the control
[e] Seawater control passes performance criteria of <30% combined mortality and abnormality
[f] This reference sample exhibited greater than 20% standard deviation (24.8) among the five replicates. The power of the t-test to detect a 20% difference between this reference and a test sediment would not be effective, so this reference is unsuitable for further comparisons.
* Sample result statistically different from reference/control sample.

4.6.3 Juvenile Polychaete Bioassay

The juvenile polychaete bioassay using the test organism *Neanthes arenaceodentata* was conducted for seven test sediments, two reference sediments, and two control sediments. The control sediments met the applicable SMS performance criteria for the polychaete test. Both reference sediments failed performance criteria for the polychaete test; however, one was accepted by Ecology for use since it was very close to the limit. SMS interpretive results were determined using the following SMS biological effects criteria:

- Fails SQS (WAC 173-204-320). The test sediment has a significantly lower (P≤0.05) mean individual growth rate than the reference sediment, and is less than 70 percent of the reference sediment.

- Fails CSL (WAC 173-204-320). The test sediment has a significantly lower (P≤0.05) mean individual growth rate than the reference sediment, and is less than 50 percent of the reference sediment.

Juvenile polychaete bioassay results are summarized in **Table 4.8**. Station DUD206 was the only station to exceed SMS biological criteria.

4.6.4 Bioassay Summary

Overall, Station DUD204 exceeded the SQS biological criteria for the amphipod test, while Station DUD206 exceeded the SQS biological criteria for both the juvenile polychaete and echinoderm larval tests. Because Station DUD206 exceeded two SQS biological criteria, this sample also exceeds the CSL and MCUL per WAC 173-204-520(3)(d). Station DUD206 is located in the intertidal area behind the E-shaped pier (South Inshore Study Area), while Station DUD204 is located just north of the E-shaped pier. Bioassay results were used to refine potential cleanup areas around the Duwamish/Diagonal outfalls (**Chapter 5**).

4.7 WASTE CHARACTERIZATION RESULTS

For initial evaluation of sediment disposal options, two Phase 2 cores were submitted for waste characterization testing. One core from the North Inshore Study Area (DUD254) and one core from the South Inshore Study Area ($DUD027_{PH2}$) were composited into 3 feet (0.91 m) sections. If contaminated sediments are dredged from the river, offsite disposal options will be based on whether the excavated material falls into one of the following waste categories:

- Washington State Dangerous Waste
- TSCA waste
- TPH-contaminated material

Waste designation criteria for the applicable regulations, as well as initial waste characterization results, are discussed below.

4.7.1 Washington State Dangerous Waste Regulations (Chapter 173-303 WAC)

The purpose of the Dangerous Waste Regulations is to designate those solid wastes that are dangerous or extremely hazardous to the public health and environment and provide guidance on generation, treatment, transportation, and disposal. Relevant sections of the Dangerous Waste Regulations are discussed below.

4.7.1.1 Excluded Categories of Waste (WAC 173-303-071 (3)(k)(i))

Certain categories of waste are excluded from the requirements of WAC 173-303-071 because they are regulated under other state or federal programs. One of these categories is PCB wastes, the disposal of which is regulated under 40 CFR 761.60 (Toxic Substances Control Act) (refer to Section 4.7.2).

4.7.1.2 Dangerous Waste Characteristics (WAC 173-303-090)

Dangerous waste characteristics include ignitability, corrosivity, reactivity, and toxicity (using the Toxicity Characteristics Leaching Procedure [TCLP]). **Table 4.9** presents the results of testing Phase 2 core sections for Dangerous Waste Characteristics. These initial results include:

- The flashpoint (measure of ignitability) of all samples was greater than 140 degrees Fahrenheit, indicating low potential for ignitability. Therefore, the sediment does not designate as Dangerous Waste based on the ignitability characteristic criteria.
- The pH (measure of corrosivity) of all samples was approximately neutral (ranging from 7.1 to 8.0), indicating low potential for corrosivity. Therefore, the sediment does not designate as Dangerous Waste based on the corrosivity characteristic criteria.
- The reactivity (as cyanide and sulfide) was measured. Cyanide was not detected in any of the samples analyzed. Sulfide was detected in two samples, at concentrations of 330 mg/kg and 61 mg/kg. Results indicate low potential for designating as Dangerous Waste based on the reactivity characteristic criteria.
- TCLP result for all samples was less than the maximum allowable concentration of contaminants (Dangerous Waste threshold value). Therefore, the sediment does not designate as Dangerous Waste based on the toxicity characteristic criteria.

4.7.1.3 Dangerous Waste Criteria (WAC 173-303-100)

Wastes may be designated as Dangerous Waste based on criteria for toxicity and persistence. For the toxicity criteria, the waste must be evaluated either by a book designation process, or by biological testing methods. Applicable biological testing (including a static acute fish toxicity test or an acute oral rat toxicity test) has not been performed on Duwamish/Diagonal sediments. Book designation procedures require the determination of the toxic category for each known constituent, calculating an equivalent concentration, and comparing the result to applicable criteria.

Persistent constituents are chemical compounds, which are either halogenated hydrocarbons (HHs), or PAHs. The total concentrations of all detected HHs and all detected PAHs are determined by summing the concentration percentages for all HHs or PAHs that are known, and comparing the result to applicable criteria. The toxicity and persistence criteria will be evaluated in the design phase of the project.

4.7.2 Toxic Substances Control Act (TSCA) (40 CFR Chapter 1 Part 761.6)

Under TSCA, dredged materials that contain PCBs at concentrations of 50 ppm (wet weight) or greater shall be disposed of in an incinerator, at a chemical waste landfill, or by another agency-approved disposal method (40 CFR Sec. 761.6 (a)(3)(iii)(E)(5)). PCB concentrations were all less than the TSCA limit of 50 ppm (wet weight).

4.7.3 Total Petroleum Hydrocarbon (TPH)

The Phase 2 core sections were also characterized for TPH, since Ecology (1995b) guidance specifies appropriate soil end uses based on TPH levels. Sediment samples were analyzed for TPH using method WTPH-HCID to identify gasoline, diesel, and oil range TPH fractions. **Table 4.9** presents TPH testing results. TPH was detected in both cores analyzed. Concentrations ranged from 833 to 19,900 mg/kg diesel, and 3,160 to 20,800 mg/kg heavy oil. Gasoline was detected at 1,220 mg/kg only in the replicate 3 to 6 foot sections collected from Station DUD027.

Table 4.9 WASTE CHARACTERIZATION RESULTS

Sample ID	Dangerous Waste Regulations		DUD027		DUD027		DUD027-Rep.		DUD027-Rep.		DUD254		DUD254	
Laboratory ID			L8542-35		L8542-36		L8542-37		L8542-38		L8542-19		L8542-20	
Sample Depth (cm)			0-90		90-180		0-90		90-180		0-90		90-180	
Sample Date			5/21/96		5/21/96		5/21/96		5/21/96		5/21/96		5/21/96	
	DW	EHW	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.	Value	Qual.
Metals (mg/L)														
Arsenic, Total	5	500	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Barium, Total	100	10000	0.0818		0.0515		0.0819		0.198		0.14		0.222	
Cadmium, Total	1	100	0.003	U	0.0042	J	0.003	U	0.003	U	0.003	U	0.003	U
Chromium, Total	5	500	0.015	J	0.005	U	0.02	J	0.0094	J	0.007	J	0.0089	J
Lead, Total	5	500	0.03	U	0.03	U	0.03	U	0.03	U	0.418		0.03	U
Mercury, Total	0.2	20	0.0002	U	0.0002	U	0.0002	U	0.0002	U	0.0002	U	0.0002	U
Selenium, Total	1	100	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U	0.05	U
Silver, Total	5	500	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U	0.004	U
Organics (ug/L)														
Benzene	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
Carbon Tetrachloride	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
Chlordane	0.03	3	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U
Chlorobenzene	100	10000	1	U	1	U	1	U	1	U	1	U	1	U
Chloroform	6	600	1	U	1	U	1	U	1	U	1	U	1	U
2-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
3-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
4-Methylphenol	200	20000	0.47	U	0.47	U	0.47	U	0.47	U	0.99		0.47	U
2,4-D	10	1000												
1,4-Dichlorobenzene	7.5	750	0.28	U	0.28	U	0.31	J	0.37	J	1.16		0.47	J
1,2-Dichloroethane	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
1,1-Dichloroethylene	0.7	70	1	U	1	U	1	U	1	U	1	U	1	U
2,4-Dinitrotoluene	0.13	13	0.19	U	0.19	U	0.19	U	0.19	U	0.19	U	0.19	U
Endrin	0.02	2	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Heptachlor	0.008	0.8	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Heptachlor Epoxide	0.008	0.8	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Hexachlorobenzene	0.13	13	0.28	U	0.28	U	0.28	U	0.28	U	0.28	U	0.28	U
Hexachlorobutadiene	0.5	50	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Hexachloroethane	3	300	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Gamma-BHC (Lindane)	0.4	40	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U	0.024	U
Methoxychlor	10	1000	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U	0.14	U
2-Butanone (MEK)	200	20000	5	U	5	U	5	U	5.1	J	5	U	5	U
Nitrobenzene	2	200	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Pentachlorophenol	100	10000	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U	0.47	U
Pyridine	5	500	2.8	U	2.8	U	2.8	U	2.8	U	2.8	U	2.8	U
Tetrachloroethylene	0.7	70	1	U	1	U	1	U	1	U	1	U	1	U
Toxaphene	0.5	50	0.24	U	0.24	U	0.24	U	0.24	U	0.24	U	0.24	U
Trichloroethylene	0.5	50	1	U	1	U	1	U	1	U	1	U	1	U
2,4,5-Trichlorophenol	400	40000	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U
2,4,6-Trichlorophenol	2	200	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U	1.9	U
2,4,5-TP (Silvex)	1	100												
Vinyl Chloride	0.2	20	1	U	1	U	1	U	1	U	1	U	1	U
WTPH (mg/Kg)														
Diesel Range (>C12 Thru C24)	NA	NA	2580		104		1310		19900		833		2010	
Gasoline Range (C7 Thru C12)	NA	NA	40	U	32	U			1220		28	U	31	U
Heavy Oil Range (>C24)	NA	NA	3540		244		2160		20800		3160		6250	
Conventionals														
Corrosivity (pH)	(2)	(2)	7.6		8		7.8		8		7.1		7.8	
Cyanide Reactivity (mg/Kg)	(2)	(2)	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U	0.5	U
Flash Point (ºF)	(2)	(2)	160	>	160	>		TIA	160	>	160	>	160	>
Sulfide Reactivity (mg/Kg)	(2)	(2)	50	U	50	U	50	U	50	U	340		110	

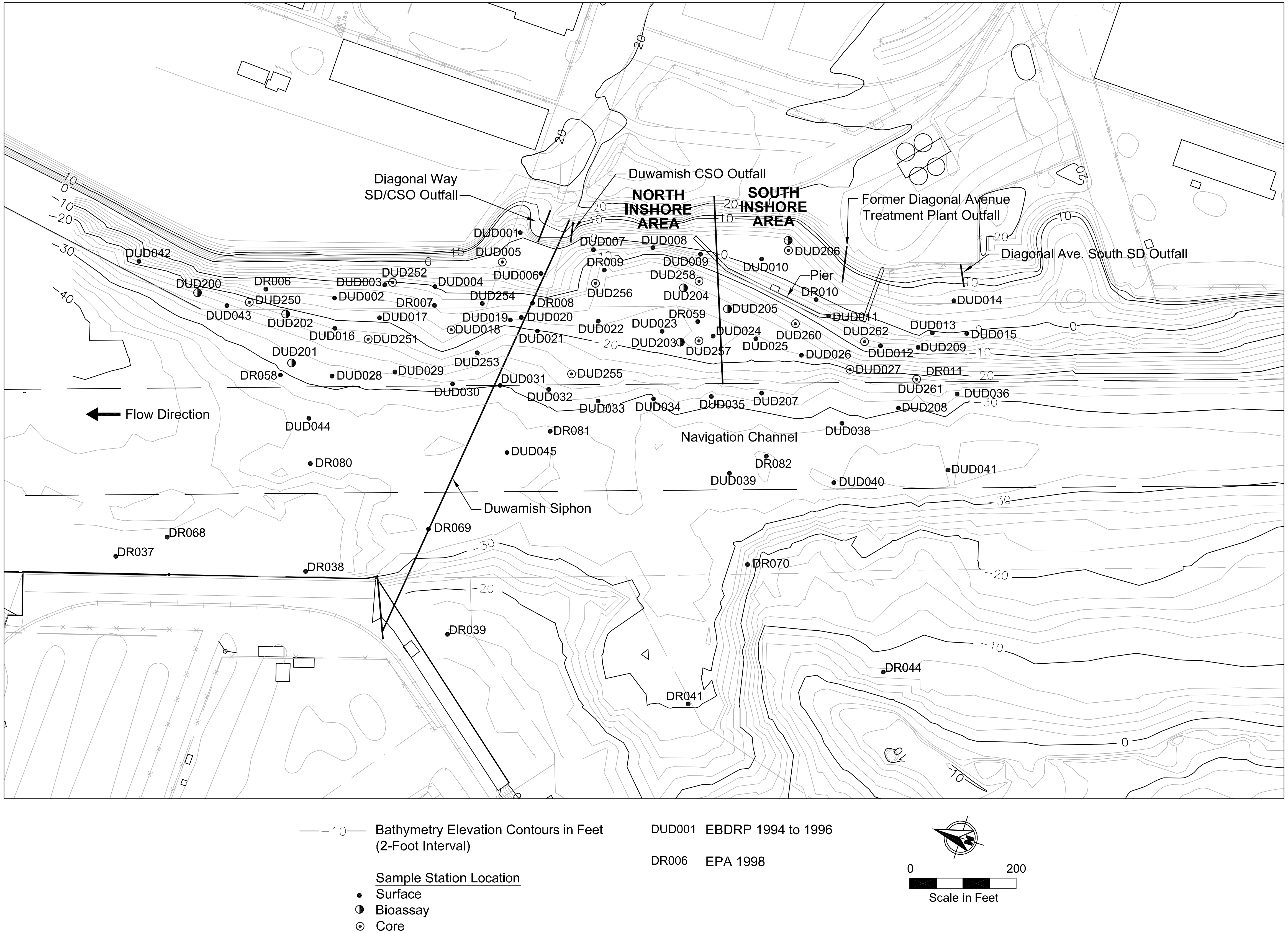
DW = Dangerous Waste

EHW = Extremely Hazardous Waste

NA = Not Available

(1) Chapter 173-303 WAC, Washington State Dangerous Waste Regulations, as amended November 1995.

(2) Narrative description in WAC 173-303-090.

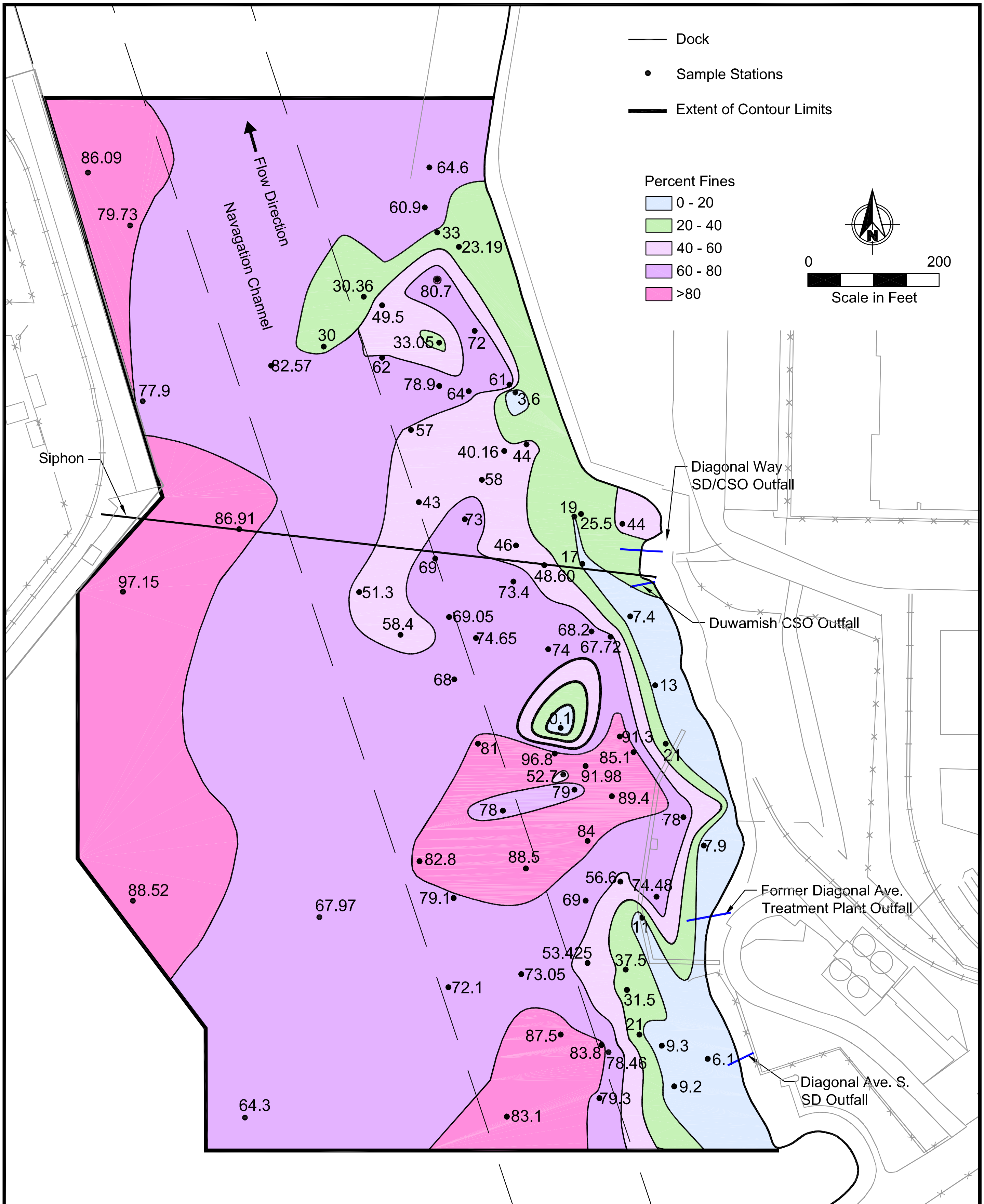


00-086-01

DWD038-01.dwg

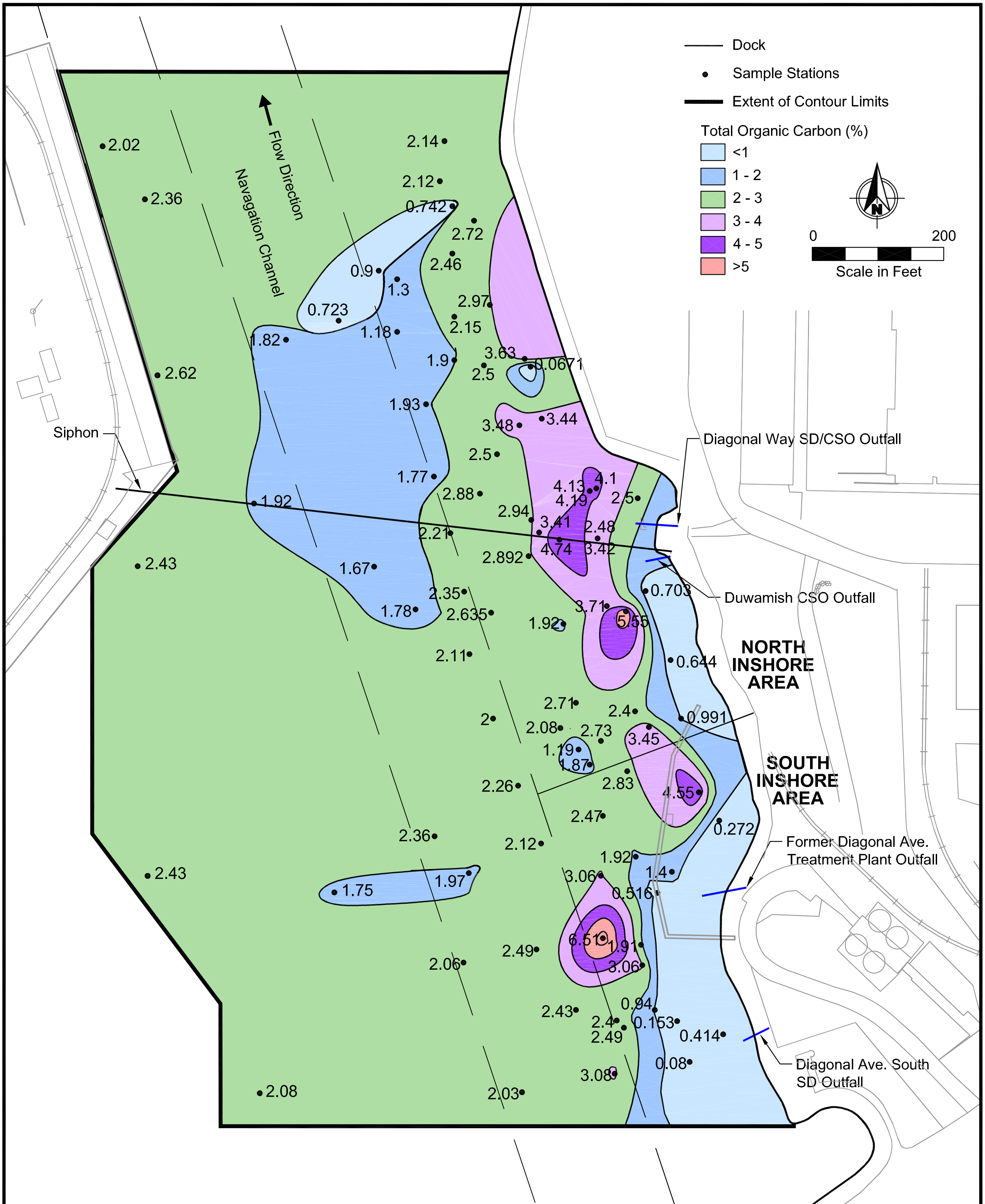
12/14/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Sampling Locations	Figure 4-1



00-086-01
DWD026-01
12/20/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 4-3
	Surface Sediment Percent Fines	

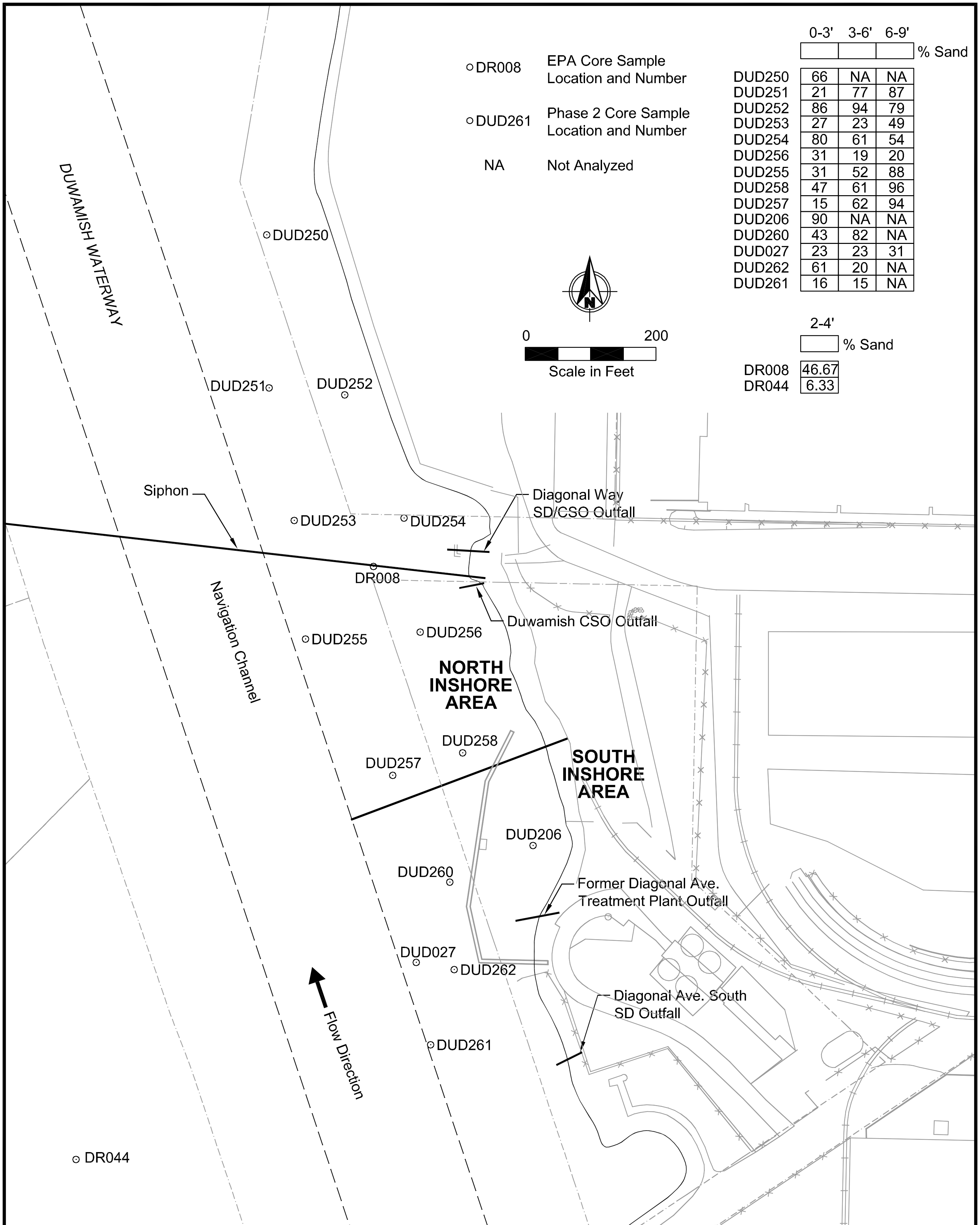


00-086-01

DWD025-01

12/14/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 4-2
	Surface Sediment Total Organic Carbon (%)	



	0-3'	3-6'	6-9'	
				% Sand
DUD250	66	NA	NA	
DUD251	21	77	87	
DUD252	86	94	79	
DUD253	27	23	49	
DUD254	80	61	54	
DUD256	31	19	20	
DUD255	31	52	88	
DUD258	47	61	96	
DUD257	15	62	94	
DUD206	90	NA	NA	
DUD260	43	82	NA	
DUD027	23	23	31	
DUD262	61	20	NA	
DUD261	16	15	NA	

	2-4'	
		% Sand
DR008	46.67	
DR044	6.33	

00-086-01
DWD024-01
12/14/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Percent Sand in Subsurface Sediments

Figure 4-4

5.0 DATA INTERPRETATION

5.1 CHEMICALS OF CONCERN

5.1.1 Selection Criteria

The EBDRP Panel has used the Washington State SMS to help establish the level of sediment cleanup. Therefore, identification of chemicals of concern (COCs) for the Duwamish/Diagonal Study Area was based on comparison to SMS marine sediment chemical criteria (i.e., SQS and CSL levels per Chapter 173-204 WAC), which are considered protective of marine organisms. There are currently no equivalent numerical SMS marine sediment chemical criteria established for the protection of human health.

The SMS provides for site cleanup standards that may range from SQS to CSL/MCUL criteria, based on a balancing of associated cost and net environmental benefit. Therefore, estimation of the areas of contaminated sediments above SQS and CSL/MCUL chemical criteria is the first step in determining potential cleanup areas for the Study Area. These potential cleanup areas may then be refined based on results of sediment bioassay testing.

Since the SMS chemical criteria do not address potential human health risks, a semi-quantitative risk evaluation was conducted to identify potential COCs for protection of human health, and to evaluate potential human health impacts due to consumption of fish harvested from the Study Area. Results of this evaluation are summarized in **Section 5.1.2.7** and included as **Appendix O**.

5.1.2 Chemicals of Concern Based on SMS Comparison

Selection of COCs for this Report focuses on conditions in the North Inshore Area because the intent of the Consent Decree is to remediate contaminated sediment associated with KCDNR and City CSOs and SDs. The North Inshore Area includes stations located near the Duwamish/Diagonal outfalls. The surface sediment characterization (**Section 4.4**) identified SQS/CSL chemical exceedances in the North Inshore Area based on 34 surface sediment samples collected. Data from the 1998 EPA study that are in the same section of river as the Duwamish and Diagonal outfalls were incorporated into the analysis as well (Weston 1999).

The number of exceedances for each COC is listed in **Table 5.1**.

Table 5.1 SQS/CSL EXCEEDANCES IN THE NORTH INSHORE AREA

Chemical	Number of SQS Exceedances	Number of CSL Exceedances
Arsenic	0	1
Lead	1	0
Mercury	5	2
Zinc	4	0
1,2-Dichlorobenzene	0	1
1,4-Dichlorobenzene	0	2
PCBs	24	6
bis (2-ethylhexyl) phthalate	9	27
Butyl benzyl phthalate	23	3
Total HPAHs	2	0
Total LPAHs	2	1
4-Methylphenol	0	2

Based on the total number of SQS/CSL exceedances, four of the chemicals listed in **Table 5.1**, mercury, PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate, are identified as COCs around the Duwamish/Diagonal outfalls. The other chemical exceedances are limited to a few stations that are remote from the Duwamish/Diagonal outfall area and do not appear to represent a contamination footprint of the outfalls.

For the primary COCs (i.e., mercury, PCBs, bis (2-ethylhexyl) phthalate, and butyl benzyl phthalate), surface concentration contour maps were generated (Figures 5-1, 5-3, 5-5, and 5-7). In addition to surface concentration contours, subsurface sediment chemistry data are also presented (Figures 5-2, 5-4, 5-6, and 5-8) to evaluate the vertical extent of contamination for each of the primary COCs.

5.1.2.1 Mercury

Figure 5-1 illustrates the concentration contours for total mercury in surface sediment. The contour plot shows three "hot spot" areas that exceed the CSL for mercury, but each area consists of only one station above the CSL. The highest concentration occurred at the station offshore from the old treatment plant outfall (five times CSL) and the next highest value was inshore and down stream of the Diagonal SD/CSO outfall (three times CSL). The third station above the CSL is located at the east channel line and a little upstream of the siphon. The SQS boundary consists of five individual SQS boundary circles (including three CSL areas). In total, there are four stations where mercury values exceed SQS and are below CSL. Two of these SQS stations are clustered with the single highest station located offshore from the old treatment plant outfall and results in the largest SQS boundary circle. The other SQS stations are located near the east channel line in two different SQS boundary circles. It appears that discharge pipes are not currently a significant continuing source of mercury.

Bioassay tests were not performed at any stations that exceed SQS or CSL values for mercury; therefore, it is not possible to determine whether toxicity is overestimated by the SMS values. All seven stations tested were below the SQS and five of these stations had no toxicity. Station DUD204 had a single toxic response (Amphipod) and station DUD206 had two toxic responses (Polychaete and Echinoderm) that are unexplained.

Figure 5-2 presents the concentration of total mercury in subsurface sediment. The maximum mercury concentration was reported at core Station DUD254, which is located adjacent to the Duwamish/Diagonal outfalls. At this station, mercury concentration exceeds CSL criteria in both the 0 to 3 feet and 3 to 6 feet segments, but is below SQS criteria in the 6 to 9 feet core segment. Thus, a decreasing mercury concentration trend with depth is evident near these outfalls. At the next downstream core station (DUD252), there are no mercury exceedances. However, mercury exceedances are noted in subsurface core segments (up to six feet deep) for core stations located further out towards the channel (DUD253 and DUD255).

Mercury that is released to the aquatic environment is chemically persistent, although its form (inorganic or organic) may change over time. The organic form (methyl mercury) is readily accumulated by fish and can present human health concerns. As indicated in **Section 4.4.2**, methyl mercury represents a small fraction (0.10 to 1.4 percent) of the total mercury concentration for Phase 1 surface sediments.

Mercury has been used in British Columbia as a marker of the extent of sediment contamination resulting from untreated sewage discharges (Chapman et al. 1996). Data presented in the Pollutant Loading Analyses for the Elliott Bay Waterfront Recontamination Study (Herrera Environmental Consultants 1995) identify a mercury concentration range of 0.38 to 3.22 mg/kg in sediments collected from within KCDNR and City CSOs. The same study presented geometric mean mercury concentrations of 0.20 to 0.26 mg/kg in particulate material discharged from storm drains from residential, commercial, and industrial areas. Finally, the KCDNR collected stormwater samples from the Diagonal Avenue storm drains system as part of the EBDRP study and reported a maximum average mercury concentration of 0.12 mg/l (**Appendix D**). KCDNR modeling results (**Appendix H**) indicate that current storm drain mercury loadings from the Diagonal Way outfall should not result in sediment recontamination following sediment cleanup. Mercury was not evaluated by the mass balance modeling activity conducted by WEST Consultants in 1999 (**Appendix I**).

5.1.2.2 PCBs

Figure 5-3 illustrates the concentration contours for total PCBs in surface sediment. The surface contours show total PCB concentrations below SQS levels near the shoreline, with concentrations increasing further offshore. CSL exceedances are present near the channel and in a larger area located off the former treatment plant outfall. The surface sediment PCB concentration contours appear unrelated to any recent discharges from the Duwamish/Diagonal outfalls, and therefore do not define the outfall footprint.

There are three distinctive "hot spot" areas for PCBs. One is located offshore from the old treatment plant outfall and this area has two stations that exceed five times the CSL (highest value 15 times CSL). The two other "hot spot" areas are located on either side of the Siphon. The "hot spot" down stream of the Siphon consists of three stations and one of these stations exceeds five times the CSL. The "hot spot" up stream of the Siphon is composed of two stations that each exceeds one times the CSL. The SQS boundary line runs along the west channel line and extends upstream to Slip 1. Most of the inshore area near the old treatment plant outfall (behind the Pier) is below the SQS. The lower PCB values near the outfalls appear to be from the more recently deposited sediments discharged from the

Diagonal SD/CSO outfall. A sediment core sample taken offshore from the Outfalls shows that there are much higher PCB values in sediments more then two feet below the present river bottom. It appears that discharges pipes are not currently a significant continuing source of PCBs. The primary source of PCB recontamination in this part of the river would be from disturbing contaminated bottom sediments.

Bioassay results show that four of the seven stations tested had less toxicity then predicted by sediment chemistry for PCBs. Stations DUD200, DUD201, DUD202, and DUD205 exceeded the SQS, but bioassays showed no toxicity. Station DUD204 was the only station that exceeded the SQS and also had one bioassay toxicity response (Amphipod). Stations DUD203 and DUD206 were below the SQS, but station DUD206 showed an unexplained toxicity in two tests (Polychaete and Echinoderm) despite low sediment chemistry.

Figure 5-4 presents the concentration of total PCBs in subsurface sediment based on EPA data (2 stations) and Phase 2 core data (16 stations). Sixteen of these stations exceed SMS values for PCBs; 13 exceed the CSL and another three are above the SQS but below the CSL. This map shows that most of the stations that exceed the SMS are located either in the channel or not far inshore from the edge of the channel. The concentrations tended to be lower near the outfalls.

At core stations located adjacent to the Duwamish/Diagonal outfalls (DUD254, DUD253), PCB concentrations slightly exceed SQS criteria in the top segment (0 to 3 feet), but exceed CSL criteria in deeper segments (3 to 6 feet, and 6 to 9 feet). An intertidal delta extends into the river in front of the Diagonal SD/CSO outfall. Chemistry data from coring stations DUD020 and DUD254 indicate that about two to three feet of sediment has accumulated on this delta since the siphon was completed in 1967. At these stations, sediments with high PCB concentrations (3,000-5,000 ppb dry weight) are covered over with two to three feet of sediments containing lower PCB values (300-700 ppb dry weight). The PCB content in deeper sediments may represent historical PCB releases, or PCBs in upper layers may have been mixed down to the deeper layer during dredging to install the siphon pipe across the river. Core stations located immediately upstream and downstream of the Duwamish/Diagonal outfalls include PCB SQS/CSL exceedances down to six feet in depth, but no exceedances in the 6 to 9 foot segments. With the exception of Station DUD206, located relatively near the shoreline, every Phase 2-core station exceeded PCB SQS or CSL criteria in the 0 to 3 feet segment.

Part of the siphon trench near the east channel line was not backfilled to the previous grade and results in a "U" shaped contour line extending towards shore. Sampling stations located on either side of this old unfilled trench, near the east channel line, (Stations DUD030 and DUD032) showed the surface sediments had greater PCB values then surface sediment located closer to the outfalls. This suggests that at the edges of this old construction trench there is an area where the historic sediments with higher PCB may be closer to surface.

The 1984 USACE emergency dredging action discussed in **Section 2-3** removed one barge load of contaminated sediment. Alex Sumeri (USACE) reported the dredged material was contaminated with numerous metals and organic chemicals including PCBs (4,500 ppb dry weight), DDD, DDE, cadmium, arsenic, copper, lead (190 ppm DW), and zinc (359 ppm DW). A slope failure is thought to have been the cause of the shoal and this could help explain why there is such a localized area of contaminated sediment remaining offshore from the old treatment plant outfall.

For comparison, total PCBs were detected in surface sediment at concentrations exceeding the SQS chemical criterion throughout the Harbor Island Inshore area, which included the East and West Waterway, north Harbor Island, and Kellogg Island (Weston 1993). PCBs were also detected throughout the sediment cores.

Current uses of PCBs are restricted to insulating materials in electrical capacitors and certain transformers employed in enclosed areas. Historically, PCBs were used in hydraulic fluids, as plasticizers in waxes, as additives in paints, adhesives, and caulking compounds, and as components in paper manufacture (Mearns et al. 1991). Thus, PCB concentrations in the site sediment are most likely due to historical discharges, rather than current sources. The potential for PCB recontamination was, therefore, not evaluated by either the KCDNR or the WEST Consultants modeling efforts. PCBs released to the aquatic environment are chemically persistent, and have a strong tendency to accumulate in aquatic sediments and in the tissue of aquatic organisms. Thus PCBs present a human health concern due to potential exposure via consumption of contaminated fish and shellfish or direct exposure to sediments.

5.1.2.3 bis (2-ethylhexyl) phthalate

Figure 5-5 illustrates the concentration contours for bis (2-ethylhexyl) phthalate in surface sediment. The contour plot shows two distinctive "hot spot" areas for bis (2-ethylhexyl) phthalate. One area near the Duwamish/Diagonal outfalls has two stations that exceed five times the CSL (highest value over six times CSL). The second "hot spot" is offshore from the former Diagonal Avenue Treatment Plant outfall and the highest value in this area is four times the CSL. Much of the CSL boundary is near the east channel line except for two circles that occur in the channel both upstream and down stream of the siphon. The SQS boundary line extends into the channel. Some of the inshore area located near the old treatment plant outfall and behind the pier is below the SQS. The old treatment plant stopped discharging in 1969 and the Duwamish CSO has not overflowed since 1989. The Diagonal SD/CSO outfall is the only continuing discharge source. The CSO volume has been reduced 80 percent (less then 65 million gallons per year remaining), but the annual volume of stormwater is about 1,230 million gallons (MGY) and could be a potential source of recontamination for bis (2-ethylhexyl) phthalate.

Only seven stations were subjected to bioassay testing in 1996 because the focus was to establish an upstream and downstream boundary for a sediment remediation project designed to address phthalate contamination. Five of the seven stations tested showed no bioassay failures (stations DUD200, DUD201, DUD202, DUD203 and DUD205), but there was one SQS exceedence (station DUD204) and one CSL exceedence (station DUD206). At five stations the bioassay results showed less toxicity than predicted by sediment concentrations of bis (2-ethylhexyl) phthalate. The largest difference was at stations DUD202 and DUD205, where both stations exceeded one times the CSL, but bioassays showed no toxicity. Station DUD200 and DUD201 exceeded the SQS, but bioassays showed no toxicity. Station DUD204 exceeded the CSL, but bioassay testing showed only one SQS exceedence (Amphipod). Station DUD203 was the only station where chemistry was below the SQS and bioassay testing gave corresponding results showing no toxicity. One intertidal station was subjected to bioassay testing (station DUD206, behind the pier), but this site gave the most conflicting results. Sediment chemistry was below the SQS, but two bioassay tests had an SQS exceedence (Polychaete and Echinoderm), that indicates the station could be listed as exceeding the CSL based on bioassay testing. All of the SMS chemicals were low at station DUD206 so the cause of the toxicity may be related to some other factors, such as ammonia or sulfides, but this has not been investigated.

Figure 5-6 presents the concentrations of bis (2-ethylhexyl) phthalate in subsurface sediment. At Station DUD254, located closest to the outfalls, CSL exceedances were reported in the 0 to 3 feet and 3 to 6 feet core segments. The SQS criteria, however, is not exceeded in the 6 to 9 feet segment. Immediately downstream, Station DUD252 had no SQS/CSL exceedances in core segments. SQS and/or CSL exceedances were found for adjacent Stations DUD253, DUD255, and DUD256 down to six feet depth; however, the numerical concentrations were not as high as reported at Station DUD254. Subsurface contamination at Stations DUD253 and DUD254, located along the siphon pipe alignment, may represent vertical mixing of the sediment during the siphon installation.

For comparison, bis (2-ethylhexyl) phthalate and butyl benzyl phthalate were most frequently detected in surface sediment at concentrations exceeding SQS chemical criteria for most of the Harbor Island Inshore area (Weston 1993); however, in the Kellogg Island area, neither phthalate frequently exceeded screening criteria.

Bis (2-ethylhexyl) phthalate released to aquatic systems will biodegrade fairly rapidly in the water column (half-life of two to three weeks) following acclimation (Howard 1989). It will also strongly adsorb to sediment due to its low water solubility, and has the potential to bioconcentrate in aquatic organisms (Howard 1989). Under aerobic conditions, bis (2-ethylhexyl) phthalate also biodegrades fairly rapidly in water/sediment systems following acclimation; however, under anaerobic conditions, no biodegradation occurs (Howard 1989).

Phthalates have been used as plasticizers since the 1930s, primarily for production of polyvinyl chloride (PVC) and other polymers. They are also used in household products. Their distribution in the environment is widespread and source control, other than control of CSO overflows, would be difficult due to their ubiquity. KCDNR has reported that the primary source of bis (2-ethylhexyl) phthalate in the Diagonal watershed may have been from historical commercial operations associated with Janco United (**Chapter 3.2.1** and **Appendix G**). In 1994 KCDNR collected stormwater samples from the Diagonal Avenue storm drain system and reported a maximum average bis (2-ethylhexyl) phthalate concentration of 7.15 mg/l (**Appendix D**). Initial KCDNR modeling results in 1996 (**Appendix H**) indicated that current storm drain bis (2-ethylhexyl) phthalate loading from the Diagonal Way outfall should not result in significant sediment recontamination following a sediment cleanup. A subsequent revision by the City in the assumed Diagonal Way SD discharge volume and subsequent modeling in 1997 by KCDNR (**Appendix H**) indicated that recontamination by bis (2-ethylhexyl) phthalate could occur. This revised conclusion lead to an attempt at mass balance modeling conducted in late 1999 by WEST Consultants (**Appendix I**). This effort also concluded that recontamination of the Study Area by bis (2-ethylhexyl) phthalate could occur due solely to background concentrations of bis (2-ethylhexyl) phthalate in the Duwamish River.

5.1.2.4 Butyl Benzyl Phthalate

Figure 5-7 illustrates the concentration contours for butyl benzyl phthalate in surface sediment. Only one station exceeded the CSL value for butyl benzyl phthalate and this station was located offshore from the old treatment plant outfall. The SQS boundary line extends primarily along the east channel line. In addition to the nearshore band of stations with levels between the SQS and the CSL there are two stations in the navigation channel with levels between the standards. The Diagonal SD/CSO outfall annually discharges about 1,230 MGY of storm water and could be a potential source of recontamination for butyl benzyl phthalate.

Bioassay results show that four of the seven stations tested had less toxicity than predicted by sediment chemistry for butyl benzyl phthalate. Stations DUD200, DUD201, DUD202, and DUD205 exceeded the SQS, but bioassays showed no toxicity. Station DUD204 was the only station that exceeded the SQS and also had one bioassay toxicity response (Amphipod). Station DUD202 and DUD206 were both below the SQS, but station DUD206 showed an unexplained toxicity in two tests (Polychaete and Echinoderm) despite low sediment chemistry.

Figure 5-8 presents the concentration of butyl benzyl phthalate in subsurface sediment. Only one station (DUD006) exceeded the CSL value for butyl benzyl phthalate and this station was located offshore between the Duwamish/Diagonal outfalls. There were a limited number of SQS exceedances, primarily limited to the 0 to 3 feet core segment. Only at Station DUD254, located adjacent to the Duwamish/Diagonal outfalls, was a SQS exceedance reported in the 3 to 6 feet core segment.

Butyl benzyl phthalate released to aquatic systems will adsorb to sediments and biota. However, biodegradation appears to be the primary fate mechanism, which can proceed rapidly under both aerobic and anaerobic conditions (Howard 1989).

Butyl benzyl phthalate is used as a plasticizer for polyvinyl and cellulosic resins, primarily in PVC. Possible sources of butyl benzyl phthalate release to the environment are from its manufacture, distribution, and PVC blending operations. Release from consumer products is expected to be minimal (Howard 1989). In 1994, KCDNR collected stormwater samples from the Diagonal Avenue storm drain system and reported a maximum average butyl benzyl phthalate concentration of 0.59 mg/l (**Appendix D**). Initial KCDNR modeling results in 1996 (**Appendix H**) indicate that current storm drain butyl benzyl phthalate loadings from the Diagonal Way outfall would require a stream mixing width of 52 feet to maintain sediment concentrations below SQS criteria. The model incorporated a stormwater concentration of 2.2 mg/l, compared to the KCDNR stormwater value of 0.59 mg/l; thus, model results were considered conservative. The mass balance modeling conducted in late 1999 by WEST Consultants (**Appendix I**) however, indicates that recontamination of a cleanup area would likely occur due solely to background concentrations of butyl benzyl phthalate in the Duwamish River.

5.1.2.5 Cleanup Areas Defined by Duwamish/Diagonal Chemicals of Concern

The surface areas for SQS/CSL chemical exceedances determined by contour plotting were overlaid for all four COCs: PCBs, mercury, butyl benzyl phthalate, and bis(2-thylhexyl)phthalate. These chemical SQS/CSL exceedance areas were then refined based on Phase 2 sediment bioassay results. Bioassays conducted for stations DUD201 and DUD202 both passed SQS biological criteria;

therefore, these stations were used to define the northern boundary of the SQS/CSL exceedance area. Similarly, bioassays were conducted for stations DUD204 and DUD205 to define a southern boundary. Station DUD205 passed SQS biological criteria, while stations DUD 204 failed SQS biological criteria, but passed CSL criteria. Therefore, the southern boundary of the SQS/CSL exceedance area was refined based on these bioassay results. The western SQS/CSL boundary was based solely on chemical exceedances, since confirmatory bioassays were not conducted in this area.

Figure 5-9 illustrates the composite SQS/CSL exceedance areas for all four chemicals of concern. The composite CSL boundary is dominated by the CSL boundary for bis (2-ethylhexyl) phthalate and PCBs. Most of the CSL boundary is near the east navigation channel line. There is a distinct "hot spot" located offshore from the old treatment plant outfall and this area had one or more stations that exceeded the CSL for all four chemicals plotted. The remaining area of CSL exceedance is centered on the outfalls and is dominated by bis (2-ethylhexyl) phthalate. Both upstream and down stream of the siphon, the CSL boundary extends to the navigation channel where station DRO81 (upstream) and station DUD044 (downstream) exceed the CSL for PCBs and bis (2-ethylhexyl) phthalate. The composite SQS boundary is driven by PCBs and includes more of the channel area. One small area below the SQS is located inshore near the old treatment plant outfall (behind the pier).

In general, the bioassay results show that sediments are less toxic than indicated by the composite sediment chemistry. The only exception to this trend is at station DUD206, which was below the SQS for all chemicals, but showed an unexplained toxic response.

Figure 5-9 also presents a proposed rectangular sediment cleanup area. This proposed cleanup area was guided by the following considerations: 1) a preferred rectangular dredge cut pattern; 2) setting the western boundary to the physical constraints imposed by the navigation channel; and 3) focusing sediment cleanup to the North Inshore Area, which represents contamination due to Duwamish/Diagonal outfall discharges. The proposed sediment cleanup area is estimated at 4.8 acres.

5.1.2.6 Relationships between Hot Spots

The two "hot spots" located upstream and down stream of the siphon extend into the channel and contain many of the same chemicals found in the "hot spot" offshore from the old treatment plant. Due to the similarities in these three "hot spots", it is possible that the 1984 emergency dredging action could have caused sediment to move from the old treatment plant area and deposit on either side of the siphon. To investigate this issue, King County staff tried to determine if there were specific chemical signatures that could confirm whether these three areas are uniquely related to each other. This limited analysis did not find any unique chemical features that could prove these three areas are composed of the same sediment material.

For surface samples, the highest concentration of PCBs (10,000 ppb - 85,000 ppb dry wt.) occurred in the three stations offshore from the old treatment plant outfall; however, within these stations there was no consistent pattern regarding which Aroclors had the highest and lowest values (Aroclor 1248, 1254, or 1260). The two "hot spots" near the siphon had lower PCB values (1140 ppb - 2440 ppb dry wt.), and neither site had a consistent Aroclor pattern. Core samples from nine stations generally appeared to have a more consistent Aroclor pattern, however this pattern was not always consistent. In general, Aroclor 1248 was highest about 80 percent of the time and Aroclor 1260 was second highest about 50 percent of the time.

Three benzene compounds (1,4-dichlorobenzene, 1,2-dichlorobenzene, and 1,2,4-trichlorobenzene) had the highest surface sediment values at station DUD027 (also some at station DUD012). These benzene chemicals were not found elevated at any other surface stations except right in front of the Diagonal SD/CSO outfall (stations DUD005 and DUD006). The core samples offshore from Diagonal SD/CSO outfall had higher values of 1,4-dichlorobenzene than the surface samples, but even these samples were not as high as the surface sample at station DUD027.

Metals do not degrade over time like organic chemicals; however, for metals to be a good tracer the concentrations need to be high enough to be distinguished from general increases. The highest concentration of metals in a surface sample occurred offshore from the old treatment plant at station DUD027 (mercury at 3.59 ppm; zinc at 900 ppm, and lead at 550 ppm dry wt.). In the "hot spot" upstream of the siphon, both stations DUD032 and DR081 had elevated levels of metals (mercury at 0.38 - 0.81 ppm; zinc at 357 - 674 ppm; lead at 255 - 411 ppm dry wt.). In the "hot spot" down steam of the siphon, only one of the three stations (DUD028) had elevated metals levels (mercury at 0.40 ppm; zinc at 487 ppm; and lead at 389 ppm dry wt.). Surface sediments off the Diagonal SD/CSO outfall are not very high for metals, but the core samples (station DUD020 and DUD254) taken in this area show there are elevated concentrations of metals buried three feet deep (mercury at l.56 ppm; zinc at 461 ppm; and lead at ll60 ppm). If these buried sediments with high metals levels were spread around during the siphon construction activities this could have influenced the two "hot spots" near the siphon. Although one cannot rule out the old treatment plant "hot spot" as a potential source of metals, the proximity of the two other "hot spots" to the siphon raises the possibility that historic construction activities could be the source.

5.1.2.7 Chemicals of Concern Based on Human Health

Identification of COCs based on screening to SMS criteria does not account for potential human health impacts, since current SMS criteria were developed for the protection of aquatic organisms only. Therefore, to assess potential human health risks due to consumption of fish harvested from the Study Area, a semi-quantitative human health risk assessment was conducted. Results of this risk assessment are summarized below, while the complete evaluation is included in **Appendix O**.

Fish tissue chemistry data were not collected as part of the Duwamish/Diagonal Site Assessment. However, fish muscle tissue data were available through the Puget Sound Ambient Monitoring Program (PSAMP) database. In 1992, PSAMP collected English sole (*Pleuronectes vetulus*) from a station located adjacent to the Duwamish/Diagonal outfalls, and analyzed the muscle tissue for a suite of contaminants. These tissue concentrations were used in standard fish ingestion equations developed by the Washington State Department of Health (1995), to determine potential carcinogenic and non-carcinogenic risks to humans due to fish consumption. Risk for exposure to non-carcinogens is considered acceptable if the calculated Hazard Quotient (HQ) is less than one (HQ < 1), while the EPA- and Ecology-acceptable carcinogenic risk probability range is from one chance in a million (10^{-6}) to one chance in ten thousand (10^{-4}) of developing cancer.

Based on the results of the human health risk assessment, PCBs, total DDT, and arsenic are potential COCs. Bis (2-ethylhexyl) phthalate was also evaluated. Results of the human health risk assessment indicate that: 1) fish tissue concentrations do not present a non-carcinogenic risk; 2) excess carcinogenic risks posed by PCBs and arsenic ($7x10^{-4}$ and $9x10^{-3}$, respectively) in fish tissue are greater than the EPA- and Ecology-acceptable carcinogenic risk probability range; and 3) concentrations of bis (2-ethylhexyl) phthalate in fish tissue do not present a carcinogenic risk ($3x10^{-7}$) or a non-carcinogenic risk (HQ = 0.0012) at the Study Area. It should be emphasized that the limited database, plus the incorporation of several conservative exposure assumptions, result in significant uncertainties in the human health risk estimates.

A 1999 human health risk assessment report prepared for the West Waterway Operable Unit of the Harbor Island Superfund Site also looked at the potential risk of eating seafood from the Duwamish River. For the highest consumption rate scenario evaluated (reasonable maximum exposure), this report listed the PCB risk in the lower Duwamish River near Kellogg Island to be elevated by two additional cases of cancer per 10,000 people (risk factor $2 X 10^{-4}$) who eat seafood potentially influenced by local bottom sediment (ESG 1999). This report listed the HQ value for PCBs at 14. A water quality report prepared by King County in 1998 determined a range of "incremental exposure increase values" for people eating Duwamish River seafood and the results included risk values that were either lower, similar, or in one case higher than the maximum consumption value in the 1999 report. The King County risk analysis included returning adult salmon, although the chemical levels in these salmon are not caused by exposure to Duwamish River sediments.

5.2 POTENTIAL FOR CONTAMINANT MIGRATION

The possible mechanisms for contaminant migration include: 1) sediment erosion and subsequent resettling; 2) sediment reworking, including bioturbation; and 3) contaminant repartitioning to the overlying water column. The Duwamish River is generally a region of sedimentation. The mudflat in front of the Diagonal Way and Duwamish outfalls is considered to be a stable depositional region created by discharged sediments from the outfalls. Estimates of sedimentation rates vary from 0.6 cm/year (EBDRP 1996b) to 5 cm/year (Harper-Owes 1983). However, a sediment transport study performed by the University of Washington estimated erosional velocities in the vicinity of the site of 16 cm/sec and observed tidal velocities of 30 cm/sec (Dail 1996). An erosional velocity of 16 cm/sec would be typical for fine sand on the order of 0.2 mm in diameter, which is typical of the bed material away from the immediate vicinity of the outfall. The report concluded that sediment erosion and migration should be expected; however, none was observed to occur. Therefore, it is not clear whether significant erosion of the existing contaminated materials near the Duwamish/Diagonal outfalls, or at upstream “hot spots,” would occur under typical tidal conditions.

As the overlying water becomes cleaner, linear-isotherm partitioning could transfer some of the contaminants from the sediment to the overlying water column. This would reduce sediment concentrations and increase water-column concentrations. Once in the lower water column, which in this location is the salt wedge, there would, on average, be transport upstream. However, because the Study Area is relatively close to the point where the Duwamish River enters Elliott Bay, the tidal flushing to Elliott Bay would be strong during the ebb tide, and overall fluxes to the water column should be quickly mixed below detection levels.

Overall, the potential for significant (sufficient to cause concern) sediment migration is unknown due to uncertainty regarding the erosion potential in the Study Area.

5.3 POTENTIAL FOR NATURAL RECOVERY

The mechanisms for natural recovery include: 1) natural sedimentation and burial; 2) sediment reworking; 3) contaminant repartitioning to the water column; and 4) chemical biodegradation.

Natural sedimentation does occur in the Duwamish River, as the river velocities decrease where the river meets salt water and the river widens. As noted above, however, actual rates are uncertain, but may be in the range of 0.6 to 5 cm/year. In addition, the potential for sediment erosion is also uncertain.

Some sediment will be reworked by a number of processes including bioturbation and vessel wake turbulence. However, these processes will generally diffuse the contamination vertically through the sediment column and thus will dilute sediment concentrations.

Contaminant repartitioning to the overlying water column could occur if the water-column concentrations were less than those estimated from equilibrium partitioning theory. Now that the Duwamish CSO discharges are successfully controlled (none since 1989), we expect to see lower ambient water column concentrations of the chemicals of concern. While contaminant concentrations in the sediment are expected to decrease, the rate of recovery is uncertain. The recovery period could be long due to the persistence of some of the chemicals of concern. The continuing stormwater discharge of 1,230 MGY plus CSO discharges from the Diagonal CSO (exceeding twenty events per year and comprising about 65 MGY) also continue to be potentially significant factors in retarding chances for natural recovery.

Of the contaminants of concern identified at the study site, both mercury and PCBs are chemically persistent and will not biodegrade. Bis (2-ethylhexyl) phthalate has been reported to undergo rapid biodegradation under aerobic conditions, but not under anaerobic conditions. Butyl benzyl phthalate can undergo rapid biodegradation under both aerobic and anaerobic conditions.

It is clear that, as contaminated discharges are controlled and contaminant sources are eliminated or reduced, natural recovery mechanisms will be enhanced for some chemicals. However, with the ongoing CSO discharges from the Diagonal CSO, it is not possible to accurately predict whether natural recovery will occur or how long "successful" natural recovery may require. It is likely that, with current conditions, the combined processes would, at best, require a relatively long time to meet sediment quality standards.

5.4 POTENTIAL FOR SEDIMENT RECONTAMINATION

The two chemical groups of greatest interest for potential recontamination at Duwamish/Diagonal are phthalates and PCBs. The most abundant phthalate is bis (2-ethylhexyl) phthalate, which is present in the stormwater discharged from the Diagonal SD/CSO outfall. Current discharges are not a concern for PCB recontamination, but care must be taken to minimize the potential that the existing PCB contaminated sediment could be disturbed in the future and pose a source of recontamination.

The PCBs present in sediments were introduced by historic sources and subsurface sediments typically have higher PCB values then surface sediments. If PCB-contaminated sediments are disturbed, they could be mobilized and then redeposited on a nearby clean sediment remediation site. The degree of recontamination would vary depending on the amount of sediment that is redeposited on the remediation site and the PCB concentrations in the redeposited sediment.

The greatest threat of PCB recontamination in this section of the river is from potential dredging activities that disturb and mobilize contaminated sediments. To minimize the risk that the future Duwamish/Diagonal sediment remediation project could be recontaminated from nearby dredging activities, it is important to identify the location of sediment contamination and the potential dredging projects that could disturb these sediments. There are several potential projects in this area that might release sediments:

1. Maintenance dredging in the navigation channel to remove a 350 meter (1150 feet) long shoal that is developing on the east side of the channel immediately upstream of the Diagonal SD/CSO outfall
2. Repair work on the two sewer siphons buried in the river bottom
3. Piling removal activities at the loading dock located offshore from the old Duwamish Avenue treatment plant outfall

Any dredging activities that cannot be completed in one dredging season would cause additional sediment disturbance in a following year, thus increasing the time during which potential recontamination could occur. Coordination of dredging projects could reduce potential recontamination. Ideally, a comprehensive plan would be developed to coordinate dredging projects and sediment remediation projects to minimize recontamination potential.

5.5 FINAL FOCUS AREA FOR ALTERNATIVES EVALUATION

Even though modeling results show phthalates will recontaminate the area near the Duwamish/Diagonal outfalls, there are factors that could justify proceeding with a sediment remediation action to remove PCBs. Some of these factors deal with the following issues: 1) the relative toxicity of the PCBs and phthalates to human health and biota, 2) the relative difficulty of achieving adequate phthalate source control to prevent recontamination, and 3) the relative size of potential phthalate recontamination compared to the total size of the PCB cleanup area.

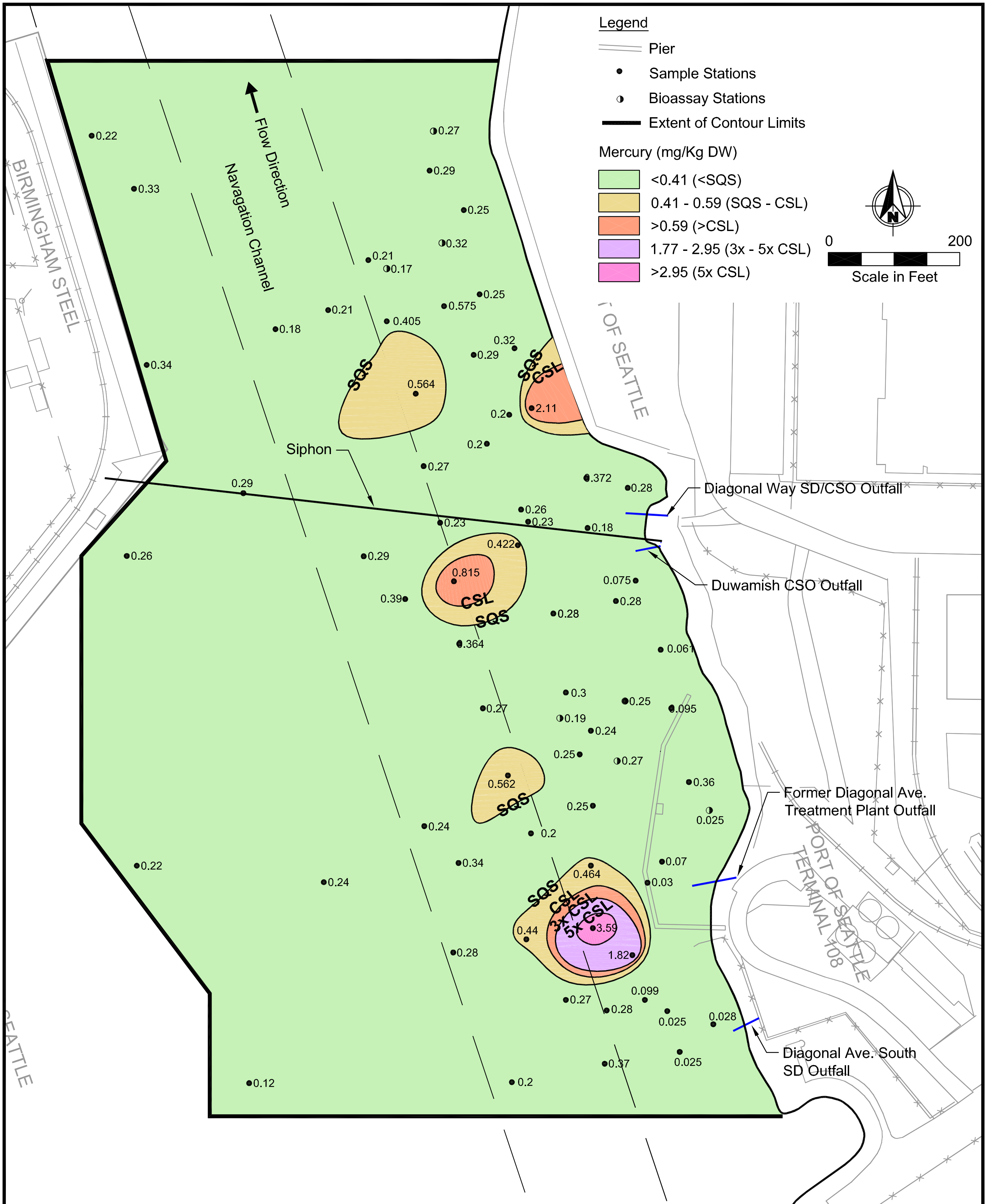
PCBs are chlorinated bioaccumulative chemicals that have been banned from production because they are toxic and persistent in the environment. Fish living in the Duwamish River have tissue concentrations of PCBs that represent an increased cancer risk of two cases in 10,000 people that consume this seafood at the highest consumption rate evaluated (ESG 1999).

The toxicity of phthalates does not appear to be as great as suggested by the SMS criteria values. Several sediment samples from the Duwamish/Diagonal study area were subjected to the three standard SMS bioassay tests. Three stations (201,202,203) showed no toxicity even though they exceeded the SMS for bis (2-ethylhexyl) phthalate. The highest concentration that showed no effects was at 1.4 times the CSL value. Similar results were found in a sediment dilution study conducted on sediments from the Thea Foss Waterway in Commencement Bay, Washington. The highest concentration of bis (2-ethylhexyl) phthalate that showed no toxicity was 1.7 times the CSL value (45 percent Thea Foss sediment plus 55 percent dilution sediment).

It may be very difficult to achieve phthalate source control in a timely manner, so the pros and cons of waiting or proceeding with a project must be examined. Phthalates are a common chemical found in stormwater and CSO discharges. Although the concentrations are fairly low, the large stormwater volume of 1230 MGY results in substantial loading. A review of business activities in the drainage basin indicates there are no major point sources to be controlled. A large outfall like Diagonal SD/CSO would require a very large and expensive treatment plant to remove the suspended particulates that contain phthalates. Sediment remediation projects will be held up a long time if phthalate source control is required in advance.

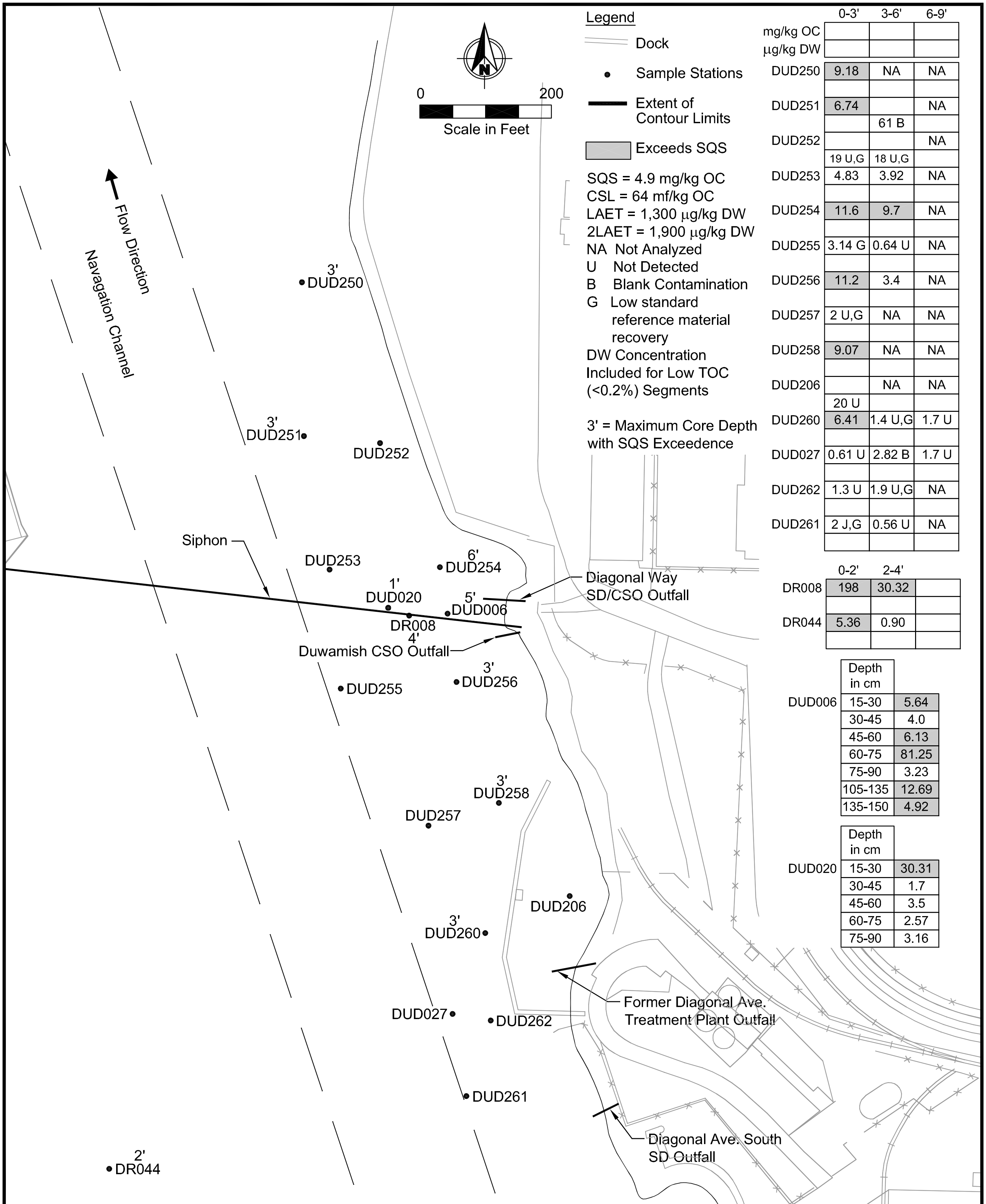
Ecology has the authority to authorize a cleanup action even if some recontamination will occur. As part of the SMS regulations there is a provision for Ecology to authorize a sediment impact zone for sediments that can be justified as not being able to meet sediment standards. There is no set limit for what percentage of the site must remain clean. Under these circumstances, the long-term goal of the SMS regulation is to achieve adequate source control and eventually eliminate the need for a sediment impact zone.

The identification of a localized area of PCB contamination in this section of the river justifies switching to the use of PCBs as the primary chemical of concern rather than phthalates. PCBs are a major chemical of concern for the Duwamish River sediment because the chlorinated compounds bioaccumulate in organisms and represent both a human health and ecological risk. Currently the local regulatory agencies have concerns about whether SQS values are low enough to protect sensitive juvenile salmon or humans from cancer. Even without comprehensive regulations regarding this chemical, the removal of PCB "hot spots" is a priority for regulatory agencies, the tribes, and project sponsors. The EBDRP panel has expressed a concern that PCBs pose a greater risk to human health and the environment than do phthalates. Because of this concern about PCBs it is considered important to move ahead with a sediment remediation action to remove PCBs even if there is a potential for part of the cleanup site to recontaminate with continuing phthalate discharges.



00-086-01
DWD029-01
12/20/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 5-1
	Mercury Concentrations in Surface Sediments	



Station	Units	0-3'	3-6'	6-9'
DUD250	mg/kg OC	9.18	NA	NA
	µg/kg DW			
DUD251	mg/kg OC	6.74		NA
	µg/kg DW		61 B	
DUD252	mg/kg OC			NA
	µg/kg DW	19 U,G	18 U,G	
DUD253	mg/kg OC	4.83	3.92	NA
	µg/kg DW			
DUD254	mg/kg OC	11.6	9.7	NA
	µg/kg DW			
DUD255	mg/kg OC	3.14 G	0.64 U	NA
	µg/kg DW			
DUD256	mg/kg OC	11.2	3.4	NA
	µg/kg DW			
DUD257	mg/kg OC	2 U,G	NA	NA
	µg/kg DW			
DUD258	mg/kg OC	9.07	NA	NA
	µg/kg DW			
DUD206	mg/kg OC		NA	NA
	µg/kg DW	20 U		
DUD260	mg/kg OC	6.41	1.4 U,G	1.7 U
	µg/kg DW			
DUD027	mg/kg OC	0.61 U	2.82 B	1.7 U
	µg/kg DW			
DUD262	mg/kg OC	1.3 U	1.9 U,G	NA
	µg/kg DW			
DUD261	mg/kg OC	2 J,G	0.56 U	NA
	µg/kg DW			

Station	0-2'	2-4'	
DR008	198	30.32	
DR044	5.36	0.90	

Station	Depth in cm	
DUD006	15-30	5.64
	30-45	4.0
	45-60	6.13
	60-75	81.25
	75-90	3.23
	105-135	12.69
	135-150	4.92

Station	Depth in cm	
DUD020	15-30	30.31
	30-45	1.7
	45-60	3.5
	60-75	2.57
	75-90	3.16

00-086-01

DWD036-01

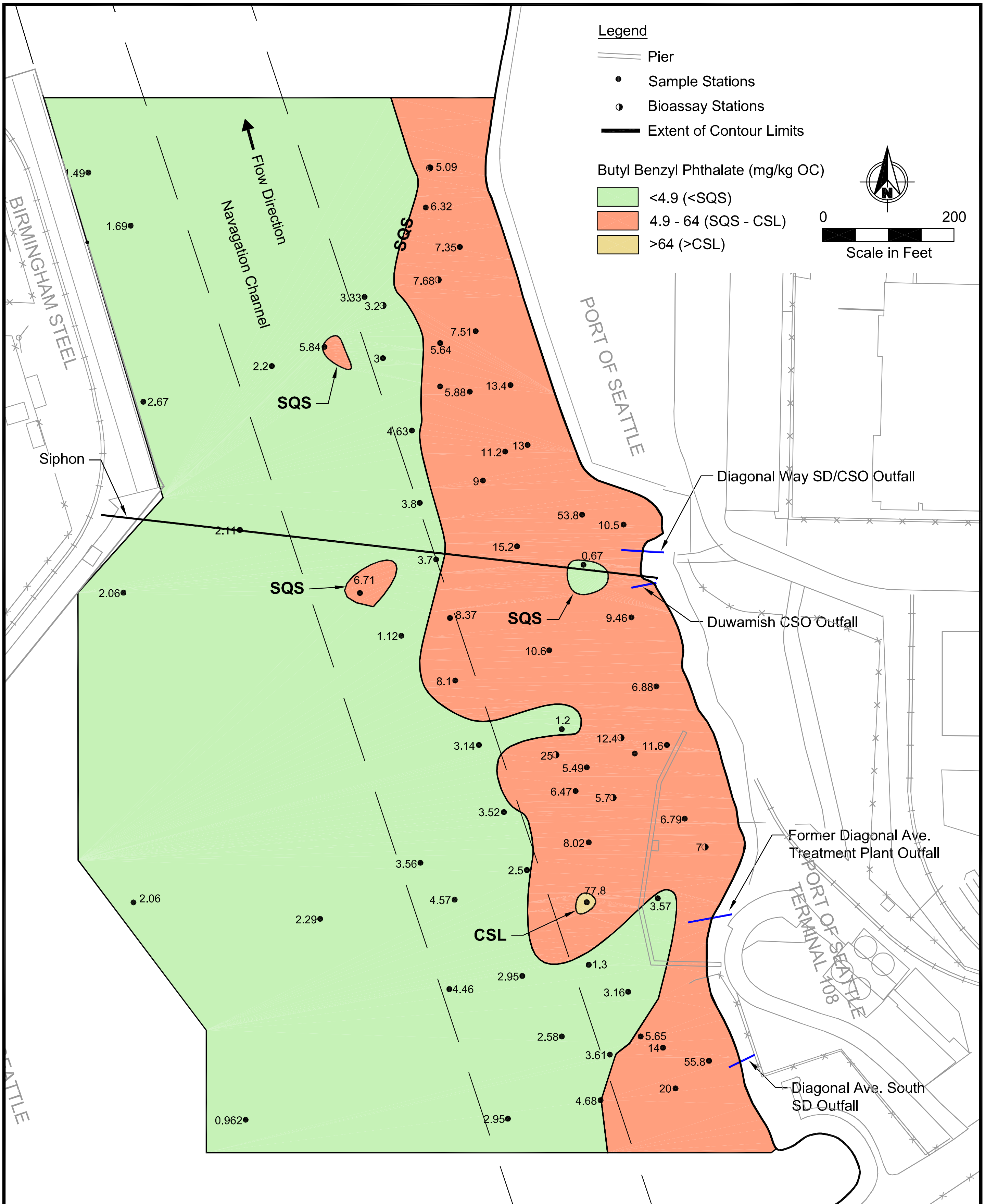
1/17/02

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Butyl Benzyl Phthalate in Subsurface Sediments

Figure 5-8



DWD035-01

00-086-01

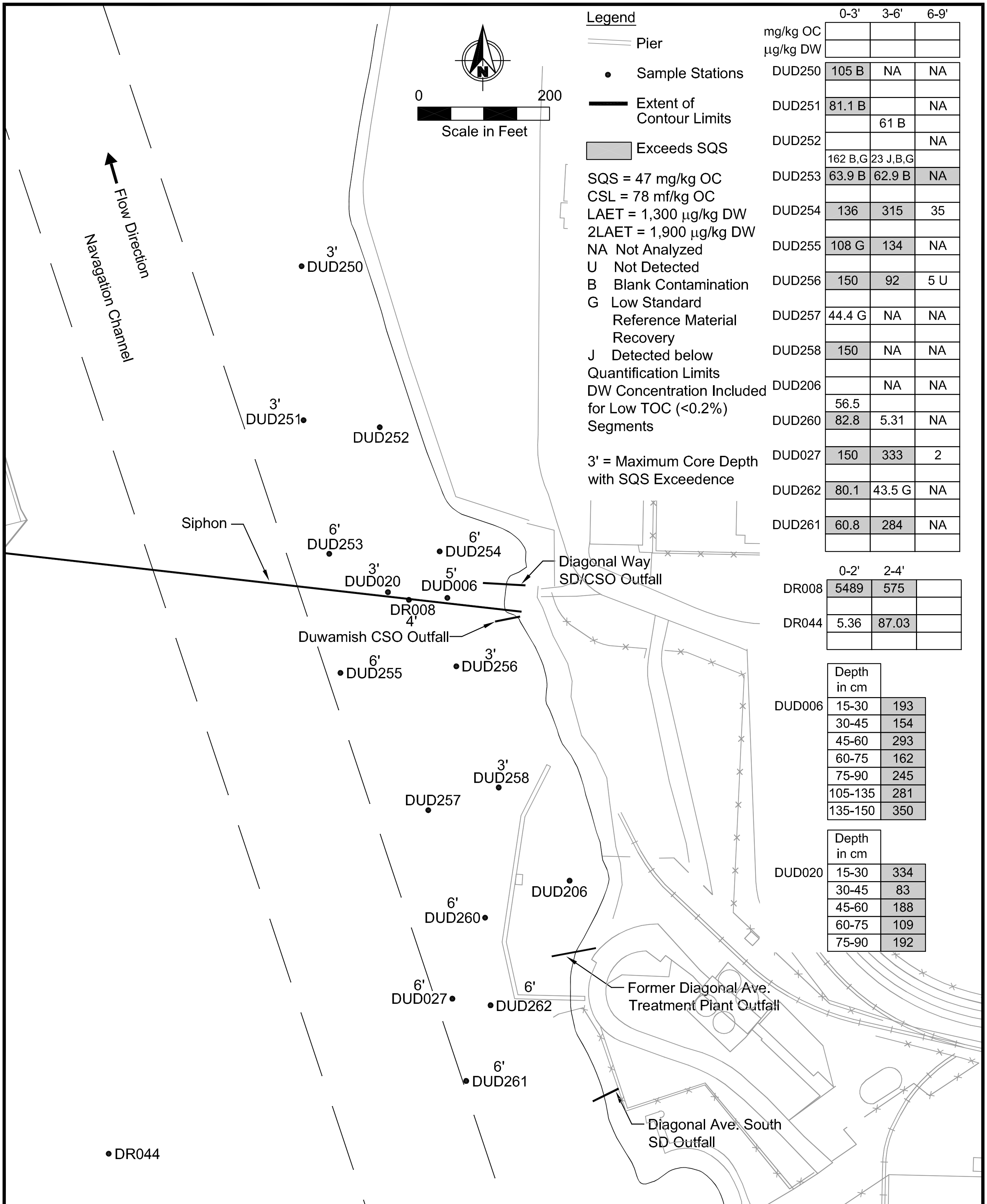
12/18/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Butyl Benzyl Phthalate (mg/kg OC) Contours in Surface Sediments (0-10 cm)

Figure 5-7



		0-3'	3-6'	6-9'
	mg/kg OC			
	µg/kg DW			
DUD250		105 B	NA	NA
DUD251		81.1 B		NA
			61 B	
DUD252				NA
		162 B,G	23 J,B,G	
DUD253		63.9 B	62.9 B	NA
DUD254		136	315	35
DUD255		108 G	134	NA
DUD256		150	92	5 U
DUD257		44.4 G	NA	NA
DUD258		150	NA	NA
DUD206			NA	NA
		56.5		
DUD260		82.8	5.31	NA
DUD027		150	333	2
DUD262		80.1	43.5 G	NA
DUD261		60.8	284	NA

	0-2'	2-4'	
DR008	5489	575	
DR044	5.36	87.03	

	Depth in cm	
DUD006	15-30	193
	30-45	154
	45-60	293
	60-75	162
	75-90	245
	105-135	281
	135-150	350

	Depth in cm	
DUD020	15-30	334
	30-45	83
	45-60	188
	60-75	109
	75-90	192

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

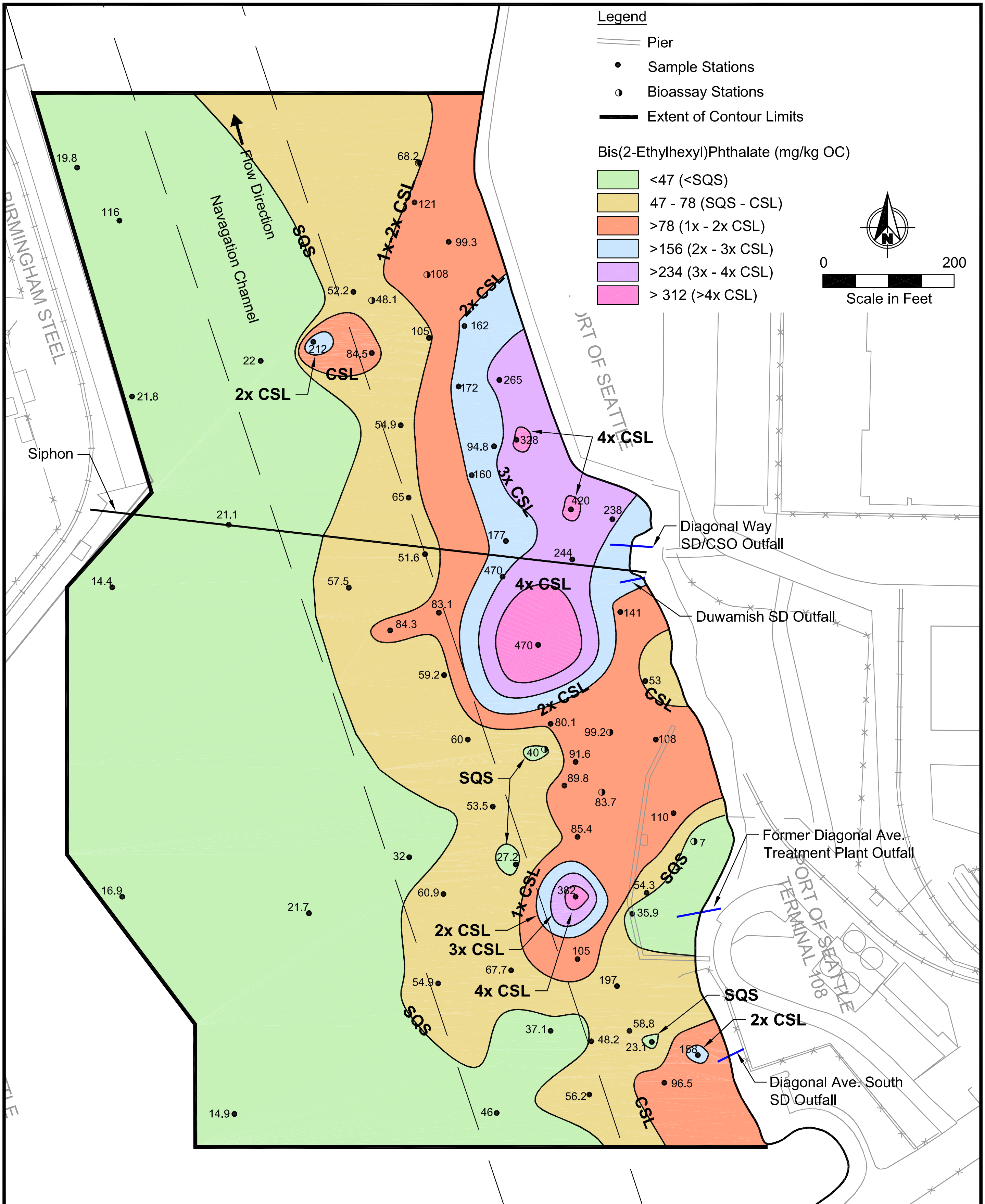
Bis(2-Ethylhexyl)Phthalate in Subsurface Sediments

Figure 5-6

00-086-01

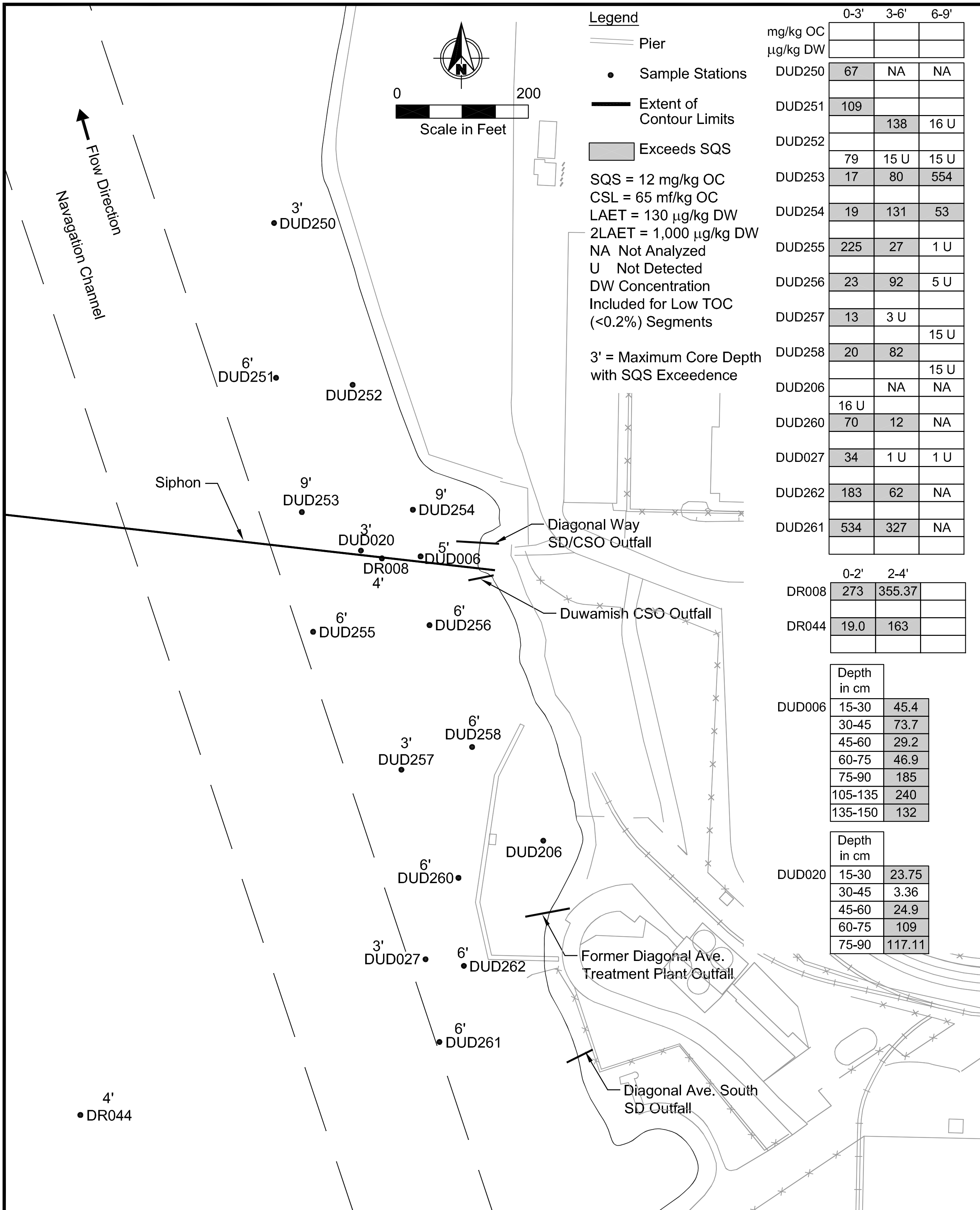
DWD034-01

1/17/02



00-086-01
DWD032-01
12/20/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 5-5
	Bis(2-ethylhexyl)phthalate Concentrations in Surface Sediments	



		0-3'	3-6'	6-9'
	mg/kg OC			
	µg/kg DW			
DUD250		67	NA	NA
DUD251		109		
			138	16 U
DUD252				
		79	15 U	15 U
DUD253		17	80	554
DUD254		19	131	53
DUD255		225	27	1 U
DUD256		23	92	5 U
DUD257		13	3 U	
				15 U
DUD258		20	82	
				15 U
DUD206			NA	NA
		16 U		
DUD260		70	12	NA
DUD027		34	1 U	1 U
DUD262		183	62	NA
DUD261		534	327	NA

	0-2'	2-4'	
DR008	273	355.37	
DR044	19.0	163	

	Depth in cm	
DUD006	15-30	45.4
	30-45	73.7
	45-60	29.2
	60-75	46.9
	75-90	185
	105-135	240
	135-150	132

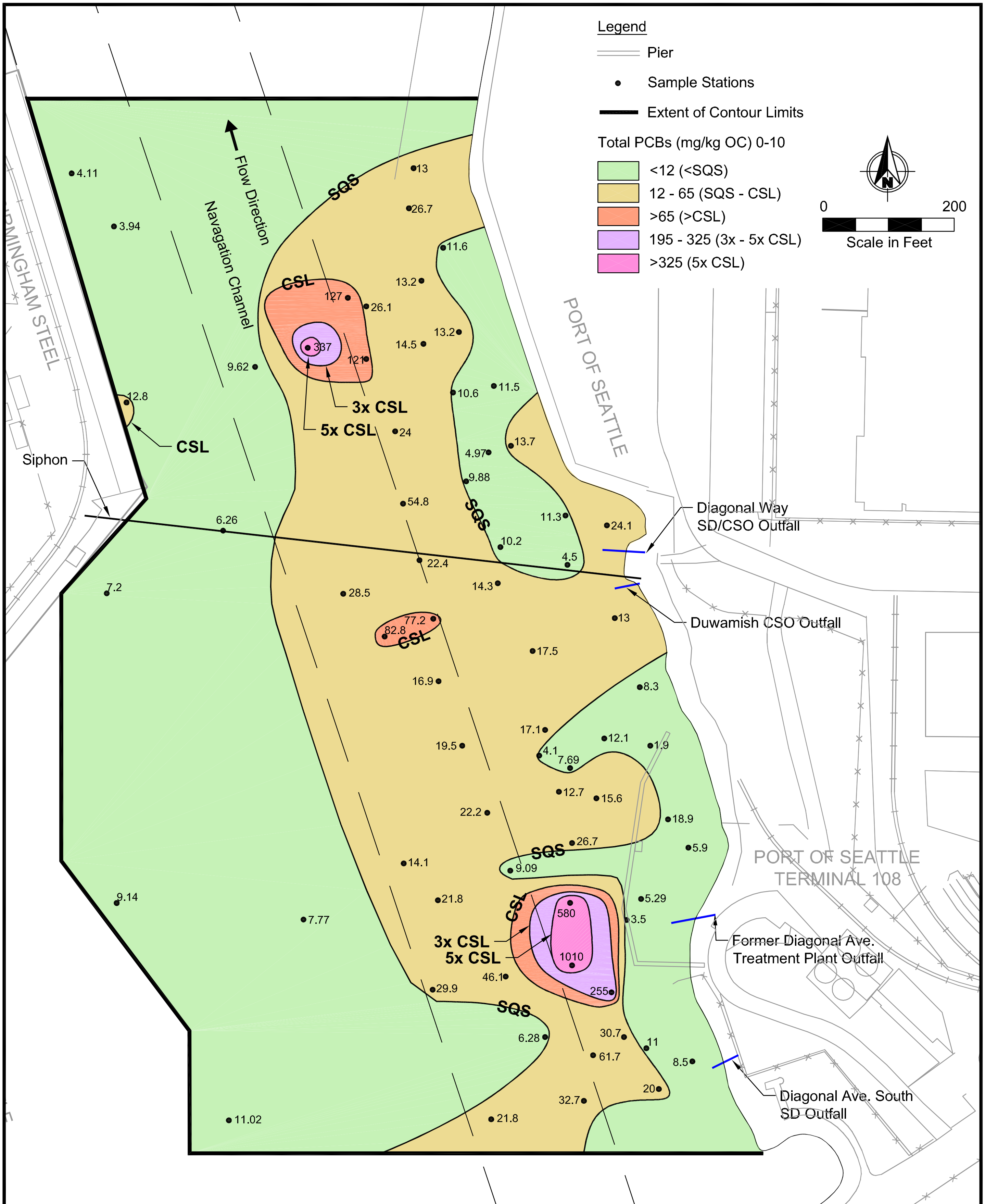
	Depth in cm	
DUD020	15-30	23.75
	30-45	3.36
	45-60	24.9
	60-75	109
	75-90	117.11

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Total PCBs in Subsurface Sediments

Figure 5-4

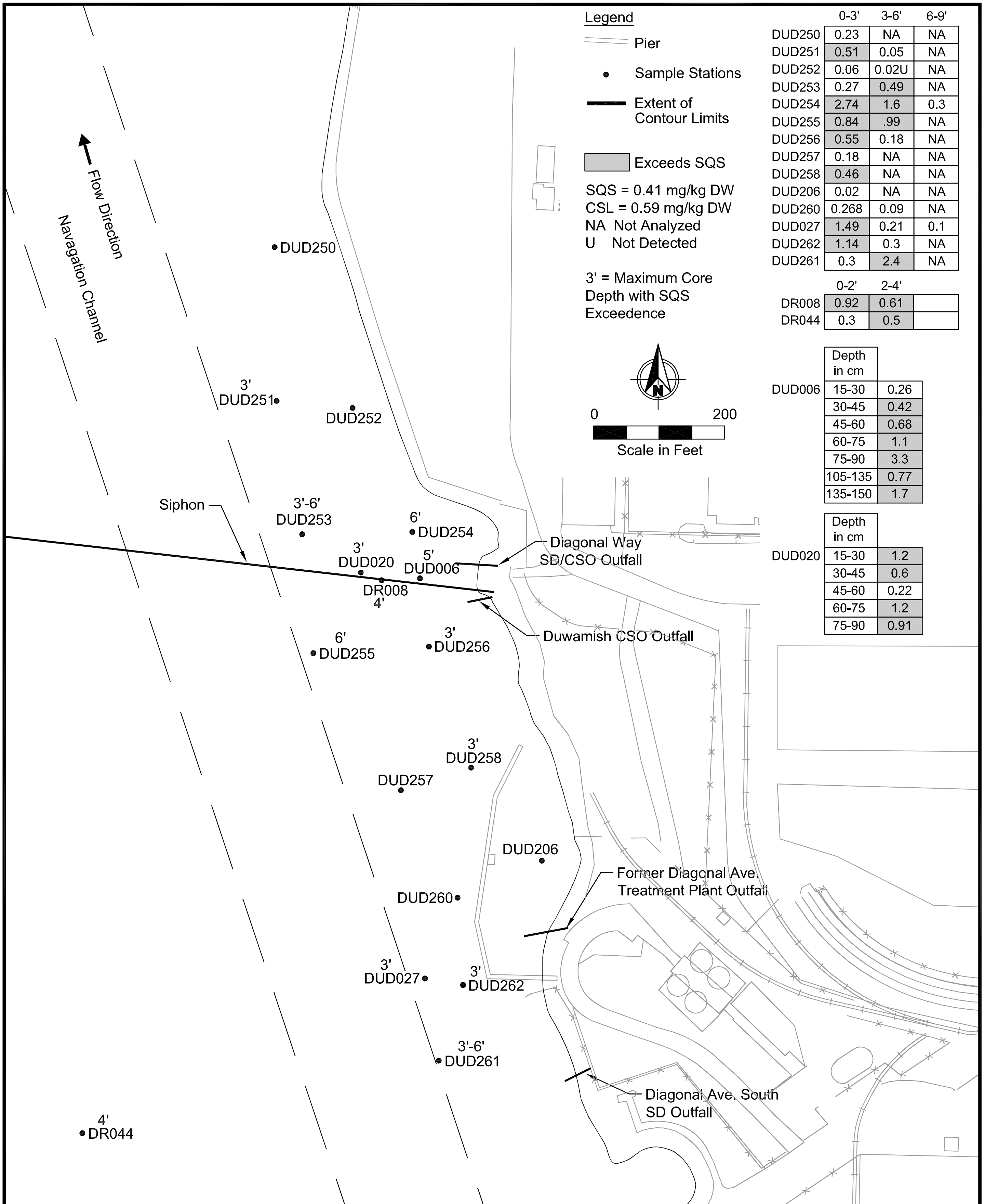


00-086-01

DWD031-01

1/17/02

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project Total PCBs (mg/Kg OC) Contours in Surface Sediments (0-10 cm)	Figure 5-3



	0-3'	3-6'	6-9'
DUD250	0.23	NA	NA
DUD251	0.51	0.05	NA
DUD252	0.06	0.02U	NA
DUD253	0.27	0.49	NA
DUD254	2.74	1.6	0.3
DUD255	0.84	.99	NA
DUD256	0.55	0.18	NA
DUD257	0.18	NA	NA
DUD258	0.46	NA	NA
DUD206	0.02	NA	NA
DUD260	0.268	0.09	NA
DUD027	1.49	0.21	0.1
DUD262	1.14	0.3	NA
DUD261	0.3	2.4	NA

	0-2'	2-4'	
DR008	0.92	0.61	
DR044	0.3	0.5	

	Depth in cm	
DUD006	15-30	0.26
	30-45	0.42
	45-60	0.68
	60-75	1.1
	75-90	3.3
	105-135	0.77
	135-150	1.7

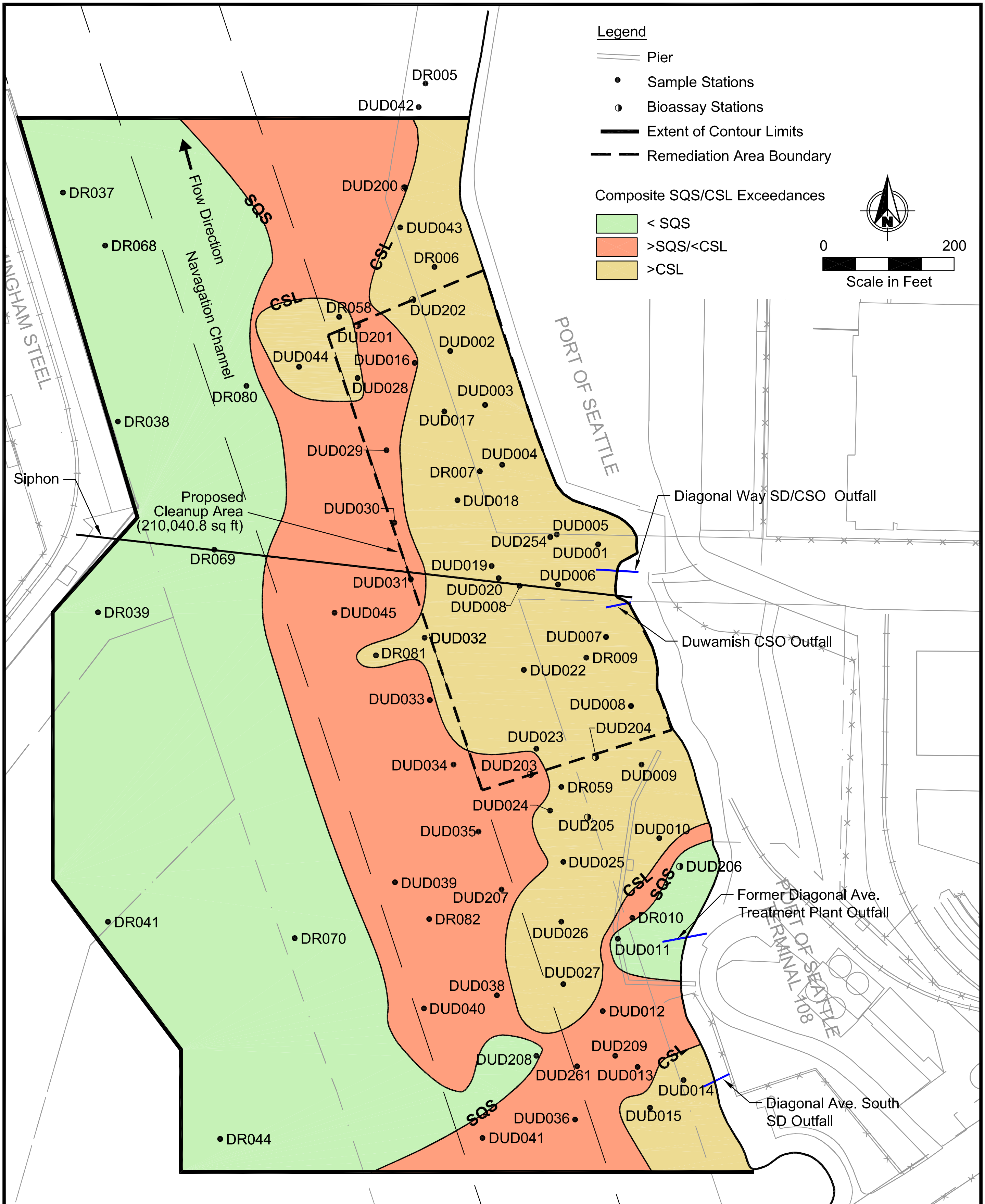
	Depth in cm	
DUD020	15-30	1.2
	30-45	0.6
	45-60	0.22
	60-75	1.2
	75-90	0.91

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Mercury Concentrations in Subsurface Sediments

Figure 5-2



EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Composite SQS/CSL Exceedance Areas

Figure 5-9

6 APPLICABLE LAWS AND REGULATIONS

6.1 IDENTIFICATION OF APPLICABLE LAWS AND REGULATIONS

This chapter presents a review of applicable laws and regulations that may govern cleanup at the Duwamish/Diagonal site, and the cleanup standards which will likely be applied to site sediments under such laws and regulations. Many federal, state, and local laws, regulations, and ordinances may affect the Duwamish/Diagonal sediment remediation project. Some of these programs directly address the management of contaminated materials, dredged material, or sediments. Other programs may impose requirements that affect the manner in which the sediment cleanup will be implemented.

The applicability of individual laws and regulations to a given cleanup action depends on a range of factors including site characteristics and location, the remedial actions selected, the substances present at the site and the exposure pathways by which contaminants at the site may become a risk to human health or the environment. A brief review of potentially applicable laws and regulations that may pertain to the Duwamish/Diagonal cleanup action is presented below.

6.1.1 Federal Laws and Regulations

6.1.1.1 Comprehensive Environmental Response, Compensation and Liability Act, 42 USC 9601 and National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR 300

The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA), also known as Superfund, and the National Oil and Hazardous Substances Pollution Contingency Plan provide the national policy and procedures to identify and clean up contaminated sites on the National Priority List (NPL). The Duwamish/Diagonal site is part of the Lower Duwamish Waterway, which was placed on the NPL on September 13, 2001, pursuant to Section 105. Consistent with this Administrative Order, a remedial investigation of Lower Duwamish Waterway is currently underway under EPA and Ecology oversight.

The Duwamish/Diagonal project was underway before the Lower Duwamish NPL listing and was proceeding as a MTCA cleanup project with Ecology as the leas regulatory agency. Now that the river has been listed, there is interest by EPA in ensuring that the Duwamish/Diagonal project is CERCLA-equivalent so that the site does not have to be revisited when EPA develops a final Superfund remedy for the entire Lower Duwamish.

6.1.1.2 Consent Decree No. C90-395 WD, U.S. District Court, Western District of Washington

CERCLA also provides for natural resource trustees to assess and seek compensation for damages to natural resources resulting from releases of hazardous materials (42 USC 9607). Under its authority as a natural resource trustee provided by CERCLA, the National Oceanic and Atmospheric Administration (NOAA) sued the City and Metro (now KCDNR) on March 19, 1990 to recover damages caused by the releases of hazardous substances discharged from their combined sewer overflows and storm drains located in the Duwamish River and Elliott Bay (EBDRP 1994a). Joining in this suit were other natural resource damage assessment (NRDA) trustees including the U.S. Fish and Wildlife Service, Ecology, Muckleshoot Indian Tribe, and the Suquamish Indian Tribe. A Consent Decree (Consent Decree 1991) was signed to settle the lawsuit, which required the City and Metro to expend a total of $24 million for source control, remediation, and habitat restoration activities to mitigate the alleged damages. This remediation at the Duwamish/Diagonal site is being performed under the authority of the Consent Decree.

6.1.1.3 National Environmental Policy Act 42 USC, 4321 et seq. and 40 CFR 1500 et seq.

The National Environmental Policy Act (NEPA) was enacted in 1969 to establish a national policy for the protection of the environment. The Council on Environmental Quality (CEQ) was established to advise the President and to carry out certain other responsibilities relating to implementation of NEPA by federal agencies. Pursuant to Presidential Executive Order, federal agencies are obligated to comply with NEPA regulations adopted by the CEQ (40 CFR Parts 1500-1508). These regulations outline the responsibilities of federal agencies under NEPA and provide specific procedures for preparing environmental documentation to comply with NEPA.

NOAA, as the lead federal agency for the NEPA process related to the Duwamish/Diagonal cleanup action, will prepare an Environmental Assessment (EA) for the action and will publish it in the Federal Register. Consistent with other similar cleanup projects, it is likely that the EA will result in a finding of no significant impact (FONSI) for this cleanup action.

6.1.1.4 Resource Conservation and Recovery Act, 42 USC 6901 and 40 CFR 260 et seq.

The Resource Conservation and Recovery Act (RCRA) was enacted to regulate the management of hazardous waste, to ensure the safe treatment, storage, and disposal of wastes, and to provide for resource recovery from the environment by controlling hazardous wastes "from cradle to grave." Because the state has been authorized to implement both Subtitles C and D of RCRA, the only regulations under the federal program would be those developed under the Hazardous and Solid Waste Act amendments for which EPA has not delegated regulatory authority to the state (e.g., land disposal restrictions). RCRA Subtitles C and D and 40 CFR 268 are applicable for upland disposal options of dredge sediments.

6.1.1.5 Clean Water Act, 33 USC 1251 et seq. and Federally Promulgated Water Quality Standards, 40 CFR 131

The Clean Water Act (CWA) requires the establishment of guidelines and standards to control the direct or indirect discharge of pollutants to waters of the United States. Effluent limitations developed for the regulated pollutants are applied to point source discharges on a case-by-case basis.

Section 304 of the CWA (33 USC 1314) requires EPA to publish Water Quality Criteria, which are developed for the protection of human health and aquatic life. These water quality criteria are promulgated in 40 CFR 131, which is also referred to as the National Toxics Rule. Federal water quality criteria are used by states to set water quality standards for surface water.

Discharges of material into navigable waters are regulated under Sections 401 and 404 of the CWA (33 USC 1341 and 1344), 40 CFR 230 (Section 404(b)(1) guidelines), 33 CFR 320 (general policies), 323 and 325 (permit requirements), and 328 (definition of waters of the United States). These requirements regulate the discharge of dredge or fill material to navigable waters of the United States. The USACE normally has the primary responsibility for administering the Section 404 permit program, which would potentially cover Duwamish/ Diagonal cleanup actions.

USACE permits are needed for the discharge of dredge or fill material into waters of the United States. There are general permits, which include permits issued by district or divisional engineers on a regional basis, and nationwide permits, which are issued by the Chief of Engineers. If a general permit does not cover the activity, an individual permit application must be filed. The Secretary of the Army acting through the Chief of Engineers authorizes the permit. Several policies are applicable to the review of permit applications which include: public interest review; effect on wetlands; fish and wildlife; water quality; historic, cultural, scenic and recreational values; effects on limits of the territorial sea; consideration of property ownership; other federal, state, or local requirements; safety impoundment and structures; water resource values; water supply and conservation; navigation; and mitigation. The public interest review involves the evaluation of probable impacts, including cumulative impacts, of the proposed activity and its intended use of the public interest. In turn, this evaluation is based on a balancing of the benefits of the proposal against its reasonably foreseeable detriments. The criteria used for this evaluation are outlined in 40 CFR 320.4.

For cleanup actions overseen by EPA and/or Ecology under applicable federal or state cleanup laws, the USACE has issued a Nationwide 38 permit that covers Section 404 requirements. However, Section 401 requires state water quality certification before 404 permits can be issued. This allows states to ensure that the action will be consistent with state and local water quality laws, and may lead to conditions placed on the 404 permit. In addition, issuance of a USACE permit also requires Endangered Species Act consultation (**Section 6.1.1.8**) and consideration of Tribal Treaties (**Section 6.1.4**).

6.1.1.6 Rivers and Harbors Act, 33 USC 403 and 40 CFR 320, 323

This Act prohibits unauthorized activities that obstruct or alter a navigable waterway. In particular, Section 10 of the Act applies to any dredging and/or disposal activity in navigable waters of the United States, including the Duwamish River. The Rivers and Harbors Act is potentially applicable to Duwamish/Diagonal cleanup actions.

6.1.1.7 Toxic Substances Control Act, 15 USC 2600 et seq. and 40 CFR 760 et seq.

The Toxic Substances Control Act authorizes the EPA to establish regulations pertaining to the control of chemical substances or mixtures that pose imminent hazards. EPA has published regulations pertaining to, among other chemicals, PCBs. 40 CFR 761 Subpart D regulates the storage and disposal of PCBs including soils and sediments excavated from regulated units which have PCB concentrations greater than 50 milligrams per kilogram (mg/kg) dry weight. PCB-contaminated materials exceeding these concentrations must be incinerated or disposed of in a qualifying chemical waste landfill. PCB-contaminated liquids may alternatively be disposed of in high efficiency boilers that meet specific criteria. The highest measured PCB value in the Duwamish/ Diagonal remediation area was 7.6 mg/kg dry weight (Station DUD255 core section 0-3 feet) which is far below the dangerous waste limit of 50 mg/kg dry weight. Thus, this Act will not determine disposal methods for the Duwamish/ Diagonal materials.

6.1.1.8 Endangered Species Act of 1973 (16 USC 1531 et seq., 50 CFR Part 200, 402) and the Magnuson-Stevens Act (Public Law 94-265, 16 U.S.C. 1801)

The Endangered Species Act provides protection for several species found in the vicinity of the project. Chinook salmon migrate through the Duwamish River, and anadromous bull trout are thought to use the river as well. Both of these species are listed as threatened. The river is part of critical habitat as defined for chinook salmon. Coho salmon also migrate through the area, and are a candidate for listing under ESA. Bald eagles, a threatened species, nest about 0.7 miles northwest of the site.

The Magnuson-Stevens Fishery Conservation and Management Act (also known as the Magnuson-Stevens Act) as re-authorized in 1996, mandates that Federal agencies consult with the Secretary of Commerce on all activities or proposed activities, authorized, funded, or undertaken by the agency that may adversely affect Essential Fish Habitat (EFH). EFH is defined as those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. In addition to Endangered Species Act consultations required for species listed as threatened or endangered, EFH consultations are required for non-listed, federally managed fishery species, which include Puget Sound coho and pink salmon populations. Pink salmon historically used the Duwamish, but have been extirpated since the mid-1930s (WDF 1975).

6.1.1.9 U.S. Fish and Wildlife Coordination Act (16 USC 661 et seq.) and the Migratory Bird Treaty Act of 1918 (16 USC 703 et seq.)

The U.S. Fish and Wildlife Coordination Act prohibits water pollution with any substance deleterious to fish, plant, or bird life, and requires consultation with the U.S. Fish and Wildlife Service and appropriate state agencies. Criteria are established regarding site selection, navigational impacts, and habitat remediation, and fill material on aquatic lands must be stabilized to prevent washout.

Migratory birds may occur in the vicinity of the site. The Migratory Bird Treaty Act requires the protection of ecosystems of special importance to migratory birds against detrimental alteration, pollution, and other environmental degradation. These requirements are anticipated to be relevant and applicable to surface or intertidal areas that may be affected by dredging or sediment disposal.

6.1.2 State Laws and Regulations

6.1.2.1 Model Toxics Control Act, Chapter 70.105D RCW and Chapter 173-340 WAC

The statute, Chapter 70.105D Revised Code of Washington (RCW), was created as a result of citizens' initiative Measure No. 97. The Model Toxics Control Act (MTCA) requires Ecology to establish and periodically update minimum cleanup standards for hazardous substances, and to investigate and remediate releases or threatened releases of hazardous substances. The most recent update of the MTCA cleanup standards became effective in August 2001.

The MTCA regulation, Chapter 173-340 WAC, also establishes administrative processes and standards to identify, investigate, and cleanup facilities where hazardous substances pose a threat to human health and the environment. Because the CERCLA Administrative Order on Consent is a joint document that also meets the requirements of a MTCA Agreed Order, MTCA is applicable to the Duwamish/Diagonal cleanup action.

6.1.2.2 Sediment Management Standards, Chapter 173-204 Washington Administrative Code

The SMS (Chapter 173-204 WAC) regulations are promulgated under MTCA, the Water Pollution Control Act (Chapter 90.48 RCW), and the Puget Sound Water Quality Authority Act (Chapter 90.52 RCW) to establish marine, low salinity, and freshwater surface sediment standards for Washington state. To date, only marine sediment standards for Puget Sound have been established. Marine sediments are defined as those sediments in which the interstitial pore water contains 25 parts per thousand (ppt) salinity or greater. Sediments within the Duwamish/Diagonal site are predominantly marine sediments (Section 1.2).

The SMS relies on chemical and biological criteria to designate sediments. Most of the chemical criteria are derived from the apparent effects threshold (AET) method, an empirical method based on Puget Sound chemistry and biological effects data. Chemical criteria are established for a no adverse effect level (Sediment Quality Standards or SQS) and a minor adverse effect level (Chemical Screening Level/Minimum Cleanup Level or CSL/MCUL). The SMS regulations recognize that a cleanup action may not achieve the objective of no adverse effects initially; therefore, minimum cleanup levels were established. These cleanup levels are the maximum allowed chemical concentration and level of biological effects permissible at the site, and often equate to levels that are expected to result in no adverse effects by year ten after completion of the active cleanup action. The SMS regulations are applicable for determining sediment cleanup standards for the Duwamish/Diagonal site.

6.1.2.3 Shoreline Management Act, Chapter 90.58 RCW and Chapter 173-14 WAC

The regulations in Chapter 173-14 WAC were developed pursuant to Chapter 90.58 RCW to protect shoreline values while still fostering reasonable use. These regulations normally require substantial development permits to be obtained for any project or action which occurs within 200 feet of the ordinary high water mark of marine waters and materially interferes with the normal public use of the water or shorelines of the state. The local government (City of Seattle Department of Construction and Land Use) issues substantial development permits (**Section 6.1.3.1**). Ecology and the Attorney General are normally sent copies of the permit by the local government for review.

As set forth in RCW 70.105D.090, qualifying cleanup actions performed under MTCA are exempt from the procedural requirements of the Shoreline Management Act, including the need for obtaining a substantial development permit. Nevertheless, as part of this MTCA authority, Ecology has the responsibility to ensure compliance with the substantive provisions of these laws, and would consult with the City of Seattle Department of Construction and Land Use, and would also provide for and receive public comment, to ensure that such substantive provisions are met. Based on an initial review of the prospective cleanup action described herein, it is not anticipated that remedial activities at the Duwamish/Diagonal site will deviate from the goals of the King County Shoreline Master Program.

6.1.2.4 Puget Sound Estuary Program

The Puget Sound Estuary Program (PSEP) was established in 1987 under the authority of the National Estuary Program, Section 320 of the Clean Water Act (33 USC 1330). The National Estuary Program was established to protect estuaries of national significance by requiring a management conference to develop a comprehensive management plan for the estuary. PSEP is jointly managed by EPA, Ecology, and the Puget Sound Water Quality Authority (PSWQA) in cooperation with federally recognized Native American Indian tribes of western Washington. The PSWQA authored the 1991 Puget Sound Water Quality Management Plan (PSWQA 1991), which was adopted by EPA as the Puget Sound Comprehensive Conservation and Management Plan. Action plans within the Plan that are applicable to the Duwamish/Diagonal site include the Contaminated Sediment and Dredging action plan, the Municipal and Industrial Discharges action plan, and the Stormwater and Combined Sewer Overflows action plan. Under Chapter 70.90 RCW, PSWQA, state agencies, and local governments are required to evaluate and incorporate as applicable, subject to the availability of appropriated funds or other funding sources, the provisions of the Plan, including any guidelines, standards, and timetables contained in the Plan. Therefore, the Plan does not have specific regulatory force but must be considered during actions that are covered by the Plan. Thus, the Plan shall be considered as guidance. Under PSEP, Puget Sound Protocols were developed to standardize the collection and analysis methods used for chemical and biological testing in Puget Sound. The use of standardized protocols by all agencies, consultants, and investigators continues to increase the usefulness of the information collected by allowing comparisons with other data collected using similar methods. The protocols are updated periodically as advances in technology and changes in needs are identified or warranted.

6.1.2.5 State Environmental Policy Act, Chapter 43.21C RCW and Chapter 197-11 WAC

The State Environmental Policy Act (SEPA), Chapter 43.21C RCW, sets forth the state's policy for protection and preservation of the natural environment. Chapter 197-11 WAC contains the state's rules to implement this act. Local jurisdictions must also implement the policies and procedures of SEPA. King County, the SEPA lead agency, will submit the response to the NEPA EA, (**Section 6.1.1.3**), for the Duwamish/Diagonal site. Ecology will review any SEPA determination. After a FONSI is issued, if applicable, the state lead will adopt the federal document. This adoption is necessary prior to the issuance of most of the other permits needed to conduct remedial activities at the Duwamish/Diagonal site.

6.1.2.6 Historic Preservation Act, Chapter 27.34 RCW, Chapter 27.44 RCW, and Chapter 27.53 RCW

This act prohibits disturbing any Native American grave sites or other historical or prehistorical archeological resources without a permit or supervision from the proper department or tribes. Because the Duwamish/Diagonal site is located in the native bed of the Duwamish River, it is not expected that any historic or prehistoric remains will be encountered. If any article is uncovered, these requirements will apply, and the Suquamish Indian Tribe and the Muckleshoot Indian Tribe, as federally recognized tribes of interest, will be consulted.

6.1.2.7 Washington Dangerous Waste Regulations, Chapter 70.105 RCW and Chapter 173-303 WAC

The regulations found in Chapter 173-303 WAC were developed to implement Chapter 70.105 RCW and are based on the state's authority to administer RCRA. The Dangerous Waste Regulations provide criteria for determining whether solid wastes that are removed during remediation are dangerous or extremely hazardous. These regulations also provide rules that apply to the generators of hazardous substances and the treatment, manifesting, transporting, disposal, and storage of these substances. Removing certain contaminated sediments from the river may constitute generation of such substances. If sufficient quantities of hazardous substances are removed such that the small quantity exemption does not apply, then these regulations will potentially be used for the dredged sediments. However, based on existing site characterization data, RCRA hazardous substances are not expected to be present at the Duwamish/Diagonal site.

6.1.2.8 Washington Hydraulic Code, Chapter 75.20 RCW and Chapter 220-110 WAC

This code establishes requirements for performing work that would use, divert, obstruct, or change the natural flow or bed of any salt or fresh waters and sets forth procedures for obtaining hydraulic project approval. The Washington State Department of Fish and Wildlife (WDFW) normally reviews proposed hydraulic projects for approval. Submittal for review includes general plans for the overall project and complete plans and specifications for the proposed construction or work below the old high waterline of state waters and for the proper protection of fish life. If the WDFW believes that the proposed project will either directly or indirectly harm fish life, the project will be denied unless adequate mitigation can be assured by conditioning the approval or modifying the proposal.

As set forth in RCW 70.105D.090, qualifying cleanup actions performed under MTCA are exempt from the procedural requirements of the Washington Hydraulic Code, including the need for obtaining a hydraulic project approval. Nevertheless, as part of this MTCA authority, Ecology has the responsibility to ensure compliance with the substantive provisions of these laws, and would consult with the WDFW to ensure that such substantive provisions are met.

6.1.2.9 NPDES Permit Program, 33 USC 1251, 40 CFR 123, Chapter 90.48 RCW and Chapter 173-220 WAC

Section 402 of the Clean Water Act (33 USC 1251) requires EPA to issue permits for the discharge of any pollutant to navigable waters. Federal regulations (40 CFR 123) allow qualifying states to issue NPDES permits. Washington's Water Pollution Control Law (Chapter 90.48 RCW) and regulations (Chapter 173-220 WAC) meet the federal requirements for the state to issue NPDES permits. Water from dewatering activities associated with dredged sediments released to the Duwamish River would be regulated under an NPDES permit or as part of the overall MTCA action. However, water from such activity could be released to a sanitary sewer, which would not require an NPDES permit but rather approval from KCDNR.

6.1.2.10 Water Quality Standards for the Surface Waters of the State of Washington, Chapter 90.48 RCW and Chapter 173-201A WAC

These regulations establish water quality standards for the surface waters of the state as required by the Clean Water Act and the Water Pollution Control Act (Chapter 90.48 RCW). Specific standards apply for many toxic substances. These surface water quality standards will be applied during all remedial activities, as applicable.

6.1.2.11 Solid Waste Management Act, Chapter 70.95 RCW and Chapter 173-304 WAC

The Solid Waste Management Act provides the State's policy on landfill and solid waste disposal requirements. The policy places emphasis on Washington's dedication to recycling. This act and implementing regulations will be used when considering upland disposal remediation alternatives. Waste reduction and recycling will be considered wherever appropriate.

6.1.2.12 State Aquatic Lands Management, Chapter 79.90 RCW and Chapter 332-30 WAC

Land use authorizations of state owned aquatic lands are administered by the Department of Natural Resources (DNR). These areas include constitutionally established harbors, state tidelands, shorelands and the beds of navigable waters. Issuance of land use authorization for activities on these public lands is based upon evaluation of the proposed use by the departments Aquatic Lands Division. State law Chapter 79.90 RCW empowers DNR to set the terms and conditions to authorize uses of state owned aquatic lands. All the DNRs aquatic land use authorizations are contractual in nature and involve limited conveyances of rights to use state owned aquatic lands. The primary administrative rule on aquatic lands that guides the DNR is Chapter 332-30 WAC, Aquatic Lands Management, which established performance standards and operational procedures for aquatic lands uses.

6.1.3 Local Laws and Regulations

6.1.3.1 Shoreline Master Program, Title 23.60 Seattle Municipal Code

The Seattle Shoreline Master Program (Title 23.60 Seattle Municipal Code) was created to implement the policies and provisions of the Shoreline Management Act (**Section 6.1.2.3**) and City Council Resolution Numbers 25173 and 27618. The Shoreline Master Programs overall goals are regulating development of shorelines to protect the ecosystem, provide maximum public use, encourage water dependent use, and preserve and increase views and access. The Seattle Shoreline Master Program provides standards for dredging and dredge disposal operations including shoreline fills. The Master Program will be considered in the decision making process during all phases of remediation.

6.1.4 Tribal Treaties

6.1.4.1 Treaty of Point Elliott, 12 Statute 927

The Treaty of Point Elliott was signed with Native American tribes occupying the lands within the Puget Sound Basin lying north of Point Pulley to the Canadian border and from the summit of the Cascade Mountains to the divide between Hood Canal and Puget Sound. The treaty guarantees the right of taking fish at usual and accustomed grounds and stations... to all the signatory tribes and other allied and subordinate tribes and bands of Native American Indians. The Duwamish River is a usual and accustomed fishing area. This treaty is applicable, and will be observed to ensure that cleanup activities do not interfere with the rights of the tribes.

6.2 CLEANUP STANDARDS

In the 1991 Consent Decree agreement, the EBDRP Panel was directed to follow the Washington state SMS as a minimum standard to determine the level of sediment cleanup. Therefore, identification of contaminated sediments for the purpose of this Report was based on comparison with numeric SMS criteria set forth in Chapter 173-204 WAC. The SMS have established cleanup standards for chemicals in marine sediments, while cleanup standards for low salinity sediments, freshwater sediments, and protection of human health are to be determined on a case-by-case basis. As discussed in Section 4.4.1.3, salinity data for surface sediments ranged from 21 parts per thousand (ppt; intertidal sediment) to 27 ppt (deep water sediment). Marine sediments are defined in the SMS as those sediments with pore water concentrations of 25 ppt or greater. Since no standards currently exist for low salinity sediments and many of the site sediments qualify as marine sediments, it is appropriate to use the marine sediment standards in the SMS.

The SMS marine chemical criteria for aquatic life are defined for two effects levels: 1) Sediment Quality Standards (SQS) criteria, which establishes a level that will result in no adverse effects on biological resources; and 2) Cleanup Screening Level (CSL) criteria, which establish minor adverse effects levels and Minimum Cleanup Levels (MCULs) that may be applicable to certain sites. The site assessment identified four chemicals of concern (i.e., mercury, bis(2-ethylhexyl) phthalate, benzyl butyl phthalate, and PCBs) associated with the Duwamish/Diagonal outfall, based on comparison to respective SQS and CSL/MCUL criteria. Chemical criteria for these substances are listed in Table 6.1. With the exception of bioaccumulative chemicals such as PCBs, compliance with SMS criteria can be demonstrated through confirmatory biological analyses. Please refer to **Section 5.1** for a more complete discussion of how confirmatory biological analyses were used to delineate the extent of exceedance of SMS criteria.

Table 6.1 POTENTIAL SEDIMENT CLEANUP STANDARDS FOR DUWAMISH/DIAGONAL CHEMICALS OF CONCERN

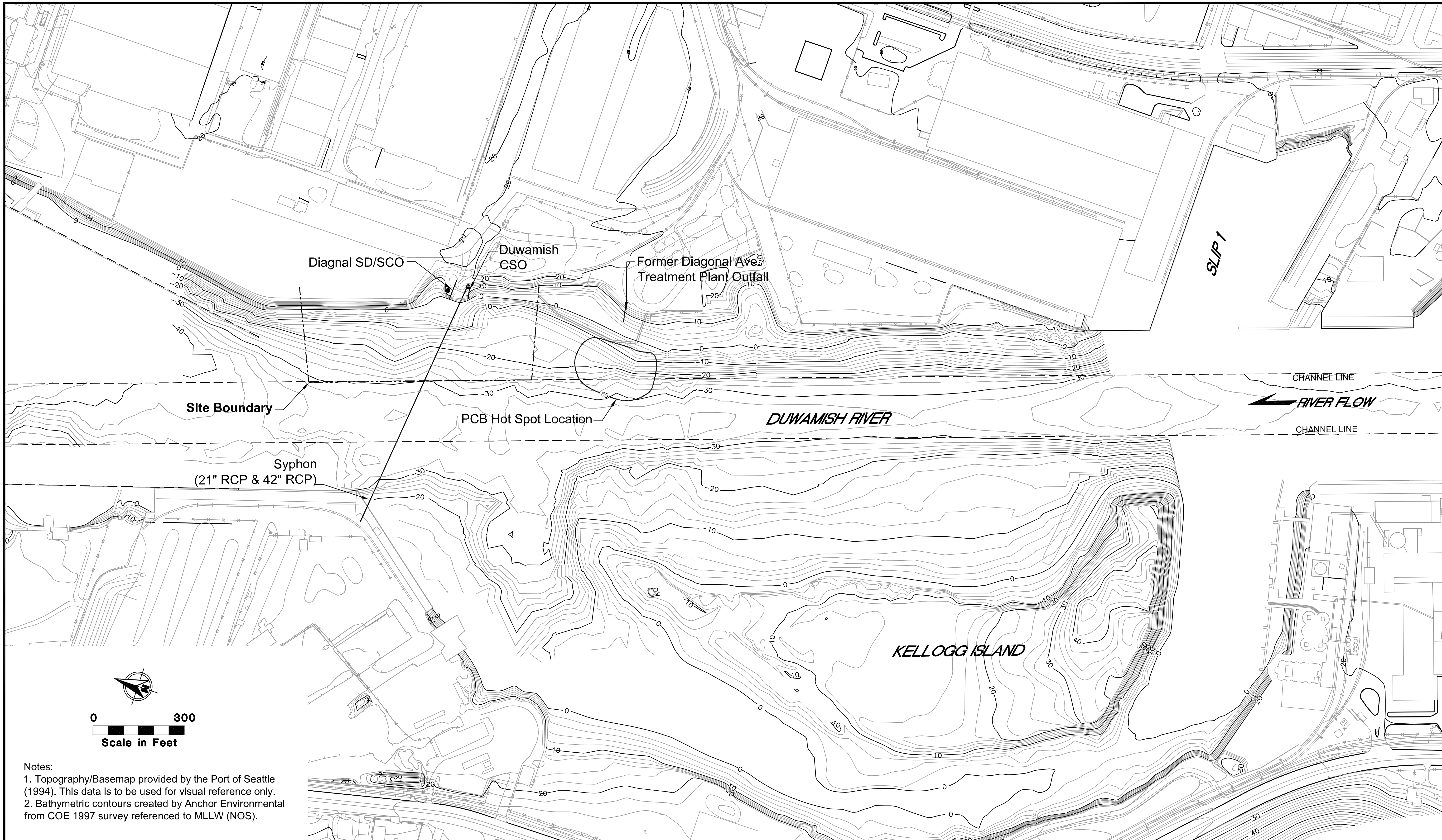
Chemical of Concern	SQS Criteria	CSL (MCUL) Criteria
Mercury	0.41 mg/Kg DW	0.59 mg/Kg DW
Bis(2-ethylhexyl) phthalate	47 mg/Kg OC	78 mg/Kg OC
Benzyl butyl phthalate	4.9 mg/Kg OC	64 mg/Kg OC
Total PCBs	12 mg/Kg OC	65 mg/Kg OC

Notes: SQS: Sediment Quality Standard CSL: Cleanup Screening Level MCUL: Minimum Cleanup Level
OC: Organic Carbon DW: Dry weight

Beyond SQS criteria, the Commencement Bay Natural Resource Trustees recognize additional sediment restoration goals for active Natural Resource Restoration projects in Commencement Bay, though similar goals have not been developed for Elliott Bay or the Duwamish River (Trustees 2000). The Commencement Bay restoration goals include numeric criteria for total PAHs (2,000 mg/Kg DW), PCBs (200 mg/Kg DW), and tributyltin (6,000 mg/Kg OC). These goals are not codified under any statute or regulation, but the Trustees' intent is that they will serve as default goals at restoration projects in Commencement Bay. These restoration goals have also been used at other cleanup sites within the Puget Sound region (e.g., as performance standards for sediment cap material placed at the Cascade Pole site in Olympia). The restoration goals were based on the Trustees' review of available information on contaminant effects and could change as further information is developed. As the Duwamish/Diagonal site is a remediation project in the Duwamish Waterway, these goals are recognized and may be used to develop performance standards for certain cleanup elements (e.g., cap material specification), but otherwise are not directly applicable to this cleanup project.

The proposed cleanup area for the Duwamish/Diagonal site is shown in **Figure 6-1**. **Chapter 5** has a more complete discussion of how the boundaries of this area were determined. The EBDRP is charged with cleaning up areas associated with historical CSO discharges. The cleanup area is proposed by the Panel to remediate past discharges that are associated with the Duwamish and Diagonal CSO outfalls.

The proposed cleanup area is approximately 4.8 acres in size and accounts for (1) all of the areas exceeding CSL; (2) a preferred rectangular dredge cut pattern; and (3) setting the offshore (western) boundary to the physical constraints imposed by the navigation channel. The downstream (northern) and upstream (southern) boundaries are set based upon sampling stations that passed SQS or CSL biological criteria (DUD 201, 202, 203, and 204). The nearshore limit is set based upon the physical constraint of the riprap bank. In general, the area extends approximately 800 feet along the east shoreline of the waterway and approximately 250 feet offshore (west) to the closest navigation channel line. Other nearby areas that exceed sediment thresholds will be evaluated through the Lower Duwamish River Superfund cleanup process.



Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).

00-0086-01

DWD005-01

12/19/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 6-1
	Site Map	

7 IDENTIFICATION AND SELECTION OF TECHNOLOGIES AND PROCESS OPTIONS

In this chapter, technologies and process options are identified for evaluation. These options represent the range of known available options capable of achieving remediation of the contaminated sediments at the Duwamish/Diagonal site.

7.1 IDENTIFICATION OF TECHNOLOGIES AND PROCESS OPTIONS

The full range of technology types and process options that potentially can be used for remediation are identified below. Technologies and process options have been compiled based on previous project experience, literature searches, and correspondence with appropriate agencies. The term "technology types" refers to general categories of technology, which for this project include:

- No Action
- Treatment
- Natural Recovery
- In-Water Containment
- Excavation
- Upland Disposal

The term "process options" refers to specific processes within each technology type. For this project, the following process options are identified:

- No Action
- Natural Recovery
- Excavation
  - Mechanical Dredging
  - Hydraulic Dredging
- Treatment
- In-Water Containment
  - In situ Capping
    - Thick Layer
    - Thin Layer
    - Inverted
  - Confined Aquatic Disposal
  - Nearshore Confined Disposal
- Upland Disposal
  - RCRA Subtitle D Landfill
  - Miscellaneous Disposal Locations
  - Construction Backfill

Technology types not identified for evaluation include in situ treatment technologies to achieve solidification, stabilization, and/or treatment. Although conceptually possible, in situ treatment technologies have not yet been adequately demonstrated or implemented to be identified at this time as capable of achieving remediation of the contaminated sediments at the Duwamish/ Diagonal site. Nevertheless, pilot testing of several innovative in situ treatment technologies is currently planned, including testing of in situ Electro Chemical Remediation Technologies at a pilot test site in Bellingham Bay. Based on the results of these and other tests, it is possible that viable in situ technologies may be identified in the future. However, given the present lack of demonstrated performance, in situ technologies were not retained in this Report.

7.2 SITE CONSTRAINTS AFFECTING CLEANUP FEASIBILITY

Three aspects of the site have been identified as influencing the feasibility of the cleanup: the long-term stability of the site, as affected by sedimentation and erosion; the known depth of contamination and constraints on excavation; and the potential for recontamination.

7.2.1 Site Sedimentation

Existing sediment grain sizes at the site vary from a relatively high percentage of fines (percent passing No. 200 sieve; silt and clay) within and adjacent to the navigation channel, to a somewhat lower percentage of fines closer to shore. This grain size pattern is consistent with normal tidal fluctuations and with wave and wake forces acting on relatively shallow sediments within the nearshore area (**Section 4.4.1.2**), and with the relatively higher current velocities in the upper water layer that occur during flood flows (Santos and Stoner 1972).

Prior to construction of the Duwamish Waterway in the early 1900s, the Duwamish/ Diagonal site was located on an intertidal/shallow subtidal beach area. Dredging of the waterway increased the local water depth in this area.

Review of two condition surveys prior to the construction of the Duwamish siphon, which occurred from approximately 1965 to 1967 (i.e., 1918 condition survey after initial construction of the Duwamish Waterway and 1931 condition survey), indicated that elevations in the Duwamish/Diagonal cleanup site had not noticeably changed during that timeframe. The 1931 condition survey also shows that elevations inside and for a short distance outside the navigation channel limits were as deep as -57 feet mean lower low water (MLLW), with an average elevation of approximately -50 feet MLLW from the East Waterway to approximate Station 49+00 (**Figure 7-1**). Average channel elevations from Station 49+00 to 57+00 (i.e., adjacent to the Duwamish/Diagonal site) were -32 to -37 feet MLLW. In contrast, current mudline elevations in this area are approximately -30 feet MLLW or shallower, indicating that there is a potential for relatively thick historical (i.e., post-1931) sediment deposits and associated contamination within and adjacent to the channel areas.

A 1967 condition survey indicated elevations from -25 feet MLLW to -29 feet MLLW in a small shelf that had originally been at 0 to -3 feet MLLW based on the 1931 survey. The decrease in elevation probably was the result of private or USACE dredging, though records have not been located to confirm this. Construction of the siphon, discussed in the following section, may also have been the cause for the deeper bathymetry. However, this is considered less likely since construction records do not indicate that material was disposed off site. Rather, the dredged material was likely sidecast and used to backfill the area dredged for the siphon (personal correspondence with Pat Romberg). Results from the core samples taken during the site assessment indicate that contamination extends to an approximate elevation of -30 feet MLLW near the navigation channel, and deeper in the areas potentially affected by siphon construction.

Comparison of the navigation channel elevations between the 1967 condition survey and the 1931 survey, indicate that significant infill occurred from the East Waterway to approximately Station 49+00. During that period, the average elevation changed from approximately -50 feet MLLW to less than -40 feet MLLW. Elevations in the navigation channel from Stations 49+00 to 57+00 do not appear to have changed significantly.

For areas of common survey coverage, no significant changes in bathymetry appear to have occurred between the 1967 USACE survey and the 1994 David Evans and Associates (DEA) survey. However, a comparison of the 1994 DEA survey and the May 1997 Condition Survey performed by the USACE shows a generalized 1-foot deposition during this 3-year period (corrected for datum differences; personal correspondence with Alex Sumeri of USACE)

USACE dredging records indicate that very little maintenance dredging activity has been required for the navigation channel adjacent to the Duwamish/Diagonal site. The last recorded maintenance activity in the Duwamish/Diagonal area occurred in 1968 (approximate Stations 51+00 to 60+00) and removed approximately 7,000 cubic yards (cy) of sediment (Appendix A of Duwamish/Diagonal Cleanup Study Workplan; EBDRP 1994b). Personal communication with the Corps of Engineers indicated that there has also been some maintenance dredging in the vicinity of the Duwamish/Diagonal site in approximately 1984 with 2,000 cy to 3,000 cy of material dredged. From the 1997 USACE survey, it appears that a recent shoal has developed along the east limit of the navigation channel at the Duwamish/Diagonal site, though it is not clear whether this was caused by deposition or slope sloughing.

All information considered, the Duwamish/Diagonal site appears to be in a historical net sediment accumulation area, and there is evidence that net accumulation is still occurring, though likely at a lower rate compared with the historical record. A recent University of Washington study (Dail 1996) at the Duwamish/Diagonal cleanup site (approximate Duwamish River Stations 49+00 to 57+00) proved inconclusive as to whether the site is erosional or depositional. Similarly, a sediment trend analysis performed by GeoSea Consulting (1994) suggested that sediments in the Duwamish/Diagonal area are now in a dynamic equilibrium, characterized by variable deposition and erosion periods. The net transport of resuspended bed sediments through the Waterway appears to be oriented to the south, towards the turning basins, consistent with current observations reported by Santos and Stoner (1972).

7.2.2 Depth of Contamination

Corps of Engineers post-dredge surveys from 1918 through 1997 were used to determine the deepest historical depths in the area. Surveys from 1918, 1925-1928, 1932, 1943, 1950, 1955, 1956, 1958, 1959, 1961, 1963, 1968, 1970, 1977, 1978, 1983, 1984, 1985, and 1997 were compared, and the deepest soundings in the areas under consideration for remediation were compiled into one map (**Figure 7-2**). Sediments below these depths were considered native sediments, and therefore with a limited potential to be contaminated.

Data from chemical analysis of sediment cores were compiled to determine the depth of contamination (relative to SQS criteria) in sediments deposited over time. Core data from the two phases of the Duwamish/Diagonal Cleanup study and from the EPA's Site Inspection Report for the Lower Duwamish were examined (**Chapter 4**). Not all the core analyses captured the depth of contamination, however.

Based on information gathered to date, it appears that the deepest sediment contamination at the Duwamish/Diagonal site is found in the area where the sewer siphon crosses the Duwamish Waterway. Cores outside of the area potentially influenced by the siphon construction indicate the bottom of contamination at approximately -30 feet MLLW while cores within the siphon influenced area indicate contamination depths greater than -30 feet MLLW.

The Municipality of Metropolitan Seattle constructed the sewer siphon across the Duwamish Waterway between 1965 and 1967. This siphon crosses the River generally east to west and passes through the cleanup site. According to a May 1967 as-built drawing included in the Duwamish/Diagonal Cleanup Study Workplan (EBDRP 1994), the siphon crosses the Duwamish Waterway at a slight angle relative to the navigation channel. The maximum depth of the invert of this siphon was constructed at an elevation of -50 feet MLLW. There are two pipes that cross, one with a 21-inch diameter and the second pipe with a 42-inch diameter. The approximate top elevation of the siphon is thus located at elevation -46.5 feet MLLW. Since the navigation channel has an authorized depth of -30 feet MLLW, there is approximately 16.5 feet of clearance from the top of the siphon to the bottom of the navigation channel. The invert elevation of the siphon at various points along its alignment are shown in Table 7.1.

Table 7.1 ELEVATIONS OF DUWAMISH SIPHON AT KEY LOCATIONS

Location	Distance along alignment	Invert Elevation (MLLW)
East end of siphon	Station 0+13	-3.6
East Channel R/W Line	Station 1+80	-50.0
East side of navigation channel	Station 3+45	-50.0
West side of navigation channel	Station 5+65	-50.0
West Channel R/W Line	Station 7+32	-50.0
West end of siphon	Station 8+52	-5.5

The siphon remains at an invert elevation of -50 feet MLLW for approximately 165 feet on either side of the navigation channel along its alignment. This is approximately halfway between the navigational channel to the eastern shoreline. Bottom sediment (mud line) elevations vary from -34 feet MLLW to -14 feet MLLW over this length and decrease to approximately -4 feet MLLW at the east end of the siphon, according to the 1997 USACE bathymetry survey of the area.

As-built drawings are not available regarding the post-siphon construction side slopes. It appears that the trench was laid back at an approximate 3H:1V slope, which is typical for construction of this type. Allowing for an 11-foot wide trench, the width of disturbed sediment during the construction of the siphon would vary from approximately 110 to 200 feet wide between Station 3+45 and Station 1+80 and from 200 feet to 20 feet wide between Station 1+80 and Station 0+13 (**Figure 7-3**). This assumes that the bathymetry depicted in the 1997 USACE survey existed at the time of construction.

As discussed above, it is likely that the material dredged for the siphon trench was sidecast along the alignment and later backfilled after construction (personal correspondence with Pat Romberg, KCDNR). This would account for the contaminant detections at depths greater than would be expected based on private dredging or Corps of Engineers maintenance dredging activity, especially at Station DUD 253. The depth of contamination near the siphon makes the option of dredging all of the contaminated material infeasible due to the need to dredge below the invert elevation of the siphon. Removal of sediment to near the top of the siphon would run the risk of damaging the siphon. Further, surveys of the exact location of the siphon would likely be required prior to performing remedial design.

7.2.3 Recontamination

The presence of contaminated surface sediments (relative to SQS criteria) located both upriver and downriver of the Duwamish/Diagonal site suggests that there is a potential for recontamination of the Duwamish/Diagonal site after cleanup. **Chapter 5** contains discussions of how the boundaries of the remediation areas were determined and the potential for contaminant migration.

For the purposes of this Report, and to support planning-level evaluations of possible sequencing of cleanup actions within the larger Duwamish Waterway area, a screening-level, semi-quantitative recontamination analysis was performed utilizing existing USACE models and available data. This analysis is described in the following section.

7.3 NATURAL RECOVERY AND RECONTAMINATION MODELING

Sediment recovery and recontamination of the Duwamish/Diagonal site was modeled under a range of possible scenarios:

1. No action
2. Site remediated, no action in adjacent, prospective PCB cleanup areas
3. Site remediated, adjacent, prospective PCB cleanup areas remediated two years later
4. Site remediated, adjacent, prospective PCB cleanup areas remediated five years later

A screening-level, semi-qualitative analysis utilizing existing models, site data, and conservative assumptions regarding river hydrodynamics, sedimentation/settling rates, contaminant concentrations, and potential dredging actions was performed to determine the degree to which natural recovery and/or recontamination by adjacent sites could occur.

7.3.1 Screening-Level Recontamination/Recovery Model

Natural recovery was defined for the purpose of this Report as the improvement of sediment quality over time with or without active remediation of the sediments, and following the implementation of upland source controls. Recontamination was defined as the deterioration of sediment quality following completion of a cleanup action, and may occur in those situations where contaminated sediments remain at locations proximal to the site. The recovery or recontamination period (depending on the scenario evaluated) begins after sediment remedial actions are completed.

The natural recovery/recontamination model used for the Duwamish/Diagonal evaluation is the diagenetic model written by Dr. Bernard Boudreau of Dalhousie University (Boudreau 1997). Among other attributes such as its relatively simple computational structure, the Boudreau model allows the user to represent important sediment bioturbation and resultant mixing of surface sediments with a Gaussian distribution, i.e., more mixing occurs at the surface than at the bottom of the representative surface mixed layer. More active mixing occurs at the surface and the amount of mixing decreases progressively with depth. Relative to other available recovery/recontamination models (e.g., SEDCAM), this depth-varying model for mixing is more representative of actual mixing characteristics generated by biological activity. This model has been used in other natural recovery evaluations in Puget Sound estuarine sites (Hylebos Cleanup Committee 1999, Anchor and Foster Wheeler 2001). The Boudreau numerical model is written in FORTRAN and uses a variable coefficient ordinary differential equation solver that is part of the ODEPACK algorithms (Hindmarsh 1983).

7.3.1.1 Advection, Diffusion, and Bioturbation of Sediment

The list of potentially relevant processes that control mixing in the sediment surface generally includes the following:

- Burrowing of organisms
- Sedimentation
- Incoming concentrations
- Lateral movement of sediment
- Resuspension
- Organic biodegradation or decay

All of these processes have been determined to be quantitatively important in modeling sediment mixing and natural recovery. For this evaluation, all of the above-listed mechanisms have been included in the model, though the magnitude of certain processes such as biodegradation were conservatively set equal to zero in this application (**Appendix P**). Lateral movement and resuspension have been included and integrated into the net sedimentation rate term applied in the model. To evaluate the potential for natural recovery and recontamination, key model input parameters were obtained from data collected at the Duwamish/Diagonal site and from similar studies in other Puget Sound estuarine waterways.

A detailed description of the Boudreau (1997) model and parameter derivation used in this application is presented in **Appendix P**.

7.3.1.2 Natural Recovery/Recontamination Model Results

Figures 7-4, **7-5**, and **7-6** summarize the results of the screening-level natural recovery/recontamination modeling. **Figure 7-5** shows the area away from the outfalls and **Figure 7-6** shows the area near the outfalls, presented as projected surface sediment PCB concentrations at the site over 10 years given different modeling scenarios. The model results can be summarized as follows:

- Natural recovery alone (i.e., no action beyond upland source control) is not expected to reduce sediment PCB concentrations below the SQS in the off shore part of the Duwamish/Diagonal site within a 10-year time frame.
- While remediation of the Duwamish/Diagonal site, including implementation of upland source controls, is expected to achieve cleanup standards for certain constituents such as bis(2-ethylhexyl)phthalate (since adjacent sediment concentrations are largely below the SQS and thus do not constitute a potential recontamination source), PCB concentrations within the half of the cleanup site away from the outfalls are predicted to recontaminate to a concentration above the SQS if adjacent sediments are not also remediated a year after completion of the Duwamish/ Diagonal cleanup action.
- The half of the site near the outfalls may recontaminate above PCB cleanup standards when adjacent areas are remediated.
- Even though dredging of adjacent sediments could result in temporary releases of contaminated sediments containing PCBs to the Duwamish/Diagonal site, the longer-term recontamination risk posed by such an action is mitigated by the ensuing acceleration of natural recovery rates effected by the overall cleanup action, such that SQS criteria are expected to be achieved throughout this area within 10 years following completion of the Duwamish/Diagonal cleanup action.

The results of the natural recovery/recontamination modeling were used in the development of remedial alternatives for the Duwamish/Diagonal site, as described in the sections below.

7.4 IDENTIFICATION/SELECTION OF TECHNOLOGIES AND PROCESS OPTIONS

A wide range of potential remedial technologies are available that could potentially be considered for application to the Duwamish/Diagonal site. However, in order to efficiently evaluate the available technologies and focus on those that are most viable for application at the Duwamish/Diagonal site, those options with a relatively low potential for application were identified early in the evaluation and screened from further analysis. Only those more promising options were retained for detailed evaluation. Consistent with CERCLA and MTCA guidance, the key criteria used in this initial technology screening were:

- Technical effectiveness. Has the technology been demonstrated to effectively remediate similar sites?
- Implementability. Is the option clearly permittable? Does the site have significant logistical problems for construction?
- Cost effective. What is the relative cost of each technology option? Between options that are similarly effective, permanent (as defined under MTCA), and implementable, those with relatively high costs may be eliminated from further consideration.
- Adverse impacts. Options that may cause significant (i.e., not easily mitigated) short- or long-term environmental or other adverse impacts may also be screened out at this early stage.

7.4.1 No Action

Under this option, no remedial action would be conducted and no institutional controls or long-term monitoring would be performed. The No Action option is not an effective technology for cleaning up the site. This option is low cost, since no actions would be performed at the site. This option is carried forward to provide a baseline for comparison.

7.4.2 Natural Recovery

This option is discussed in more detail in **Section 7.3**. Under this option, upland source controls would be implemented, but no in-water cleanup actions would be performed. Institutional controls would be implemented and long-term monitoring performed as an element of this alternative.

The screening-level natural recovery modeling performed for this report (**Section 7.3** and **Appendix P**) predicted that natural recovery alone would not be effective as a remedial action for the site. However, this process option may be effective in addressing recontamination that may occur during remedial activities occurring on adjacent sites, and thus may be appropriate as a component of a more active remedial option (e.g., capping or dredging). Because of its limited effectiveness, and also because this option is unlikely to comply with MTCA cleanup standards, natural recovery as a sole process option was eliminated as a remedial technology for the Duwamish/Diagonal site. However, as noted above, natural recovery may be appropriate for consideration as a component of a more active cleanup remedy.

7.4.3 Excavation Options

Sampling results indicate that the potential bottom elevation of sediment contamination at the Duwamish/Diagonal site is approximately -50 feet MLLW at the siphon crossing. It appears infeasible to dredge and completely remove all contaminated sediment from the site, since the existing siphon would need to be demolished and reconstructed in order to accomplish such an action. This would significantly affect the sanitary sewer system that serves West Seattle; therefore, total removal was not considered further in this evaluation.

Contaminated sediment may be removed (excavated) using either mechanical (e.g., clamshell) or hydraulic (e.g., cutterhead) technologies. Applying the screening criteria to excavation options yields the following results:

Dredging (mechanical). Mechanical dredging used in conjunction with capping (i.e., to contain subsurface sediments at the siphon crossing) may be an effective remedial technology for this site. This option is proven and routinely applied at other similar sediment cleanup sites, and permitting has been accomplished with water quality and fisheries conditions acceptable to a range of applicants. Even though dredging could result in temporary releases of contaminated sediments to adjacent areas, the longer-term recontamination risk posed by such an action is mitigated by the ensuing acceleration of natural recovery rates (**Section 7.3**). Water quality and sediment controls can also be implemented to further reduce short-term impacts during construction. Depending largely on final water quality and fisheries conditions, mechanical dredging can be cost effective. This option was carried forward for further analysis.

Dredging (hydraulic). Although hydraulic dredges (e.g., cutterheads) resuspend a somewhat lower quantity of sediments (typically by a factor of 3 or more) compared to mechanical dredges, due to the large amount of water entrained during the hydraulic dredging process (typically 80 to 90 percent water by weight), logistics are significantly more complex than for mechanical dredging. The design must account for handling and possibly treatment of the water that is entrained prior to its return to the receiving water. Hydraulic dredging is typically used to remove sediments and transport them directly to a nearby upland or nearshore fill disposal site. The availability of nearby disposal sites, however, is questionable, as discussed in **Section 7.4.5**. Further, because prospective sediment disposal volumes at the Duwamish/Diagonal site (approximately 81,000 cy) are relatively small by normal hydraulic dredging standards, this option would likely be associated with relatively large setup costs for the pipeline and water treatment facility. These factors render this option considerably less promising than mechanical dredging. As there is considerable uncertainty associated with a hydraulic dredging option at this site, and because there is a more proven and likely more cost-effective option available (mechanical dredging), hydraulic dredging was eliminated from further consideration.

7.4.4 Treatment Options

Contaminated sediment treatment has received increasing attention and evaluation over the last several years, at both the federal and state levels. For example, the Washington Department of Natural Resources (WDNR) recently issued a report assessing several sediment treatment alternatives that could potentially be implemented as part of a multi-user facility servicing the Puget Sound region (Hart Crowser 2001). Seven venders with five different treatment technologies were addressed in a preliminary engineering and economic analysis. These technologies evaluated by WDNR included:

- Biological Treatment
- Soil Washing
- Lightweight Aggregate
- Plasma Arc

- Stabilization

Based on WDNR’s analyses, several of these technologies were identified as potentially viable for application at a Sediment Multi-User Remediation Facility (SMURF) at an offsite location. However, there is no existing SMURF in the Puget Sound area, and the prospective viability and availability of such a facility is uncertain. The WDNR focused their prospective SMURF evaluation towards a hypothetical site located in Everett, Washington, though the analysis could be generally applicable to other potential SMURF sites with similar attributes. WDNRs preliminary analysis concluded that if a SMURF were to be owned, constructed, permitted, and operated by a third party entity (i.e., separate from the WDNR and the owner/generator of the sediments), it may be reasonable to expect tipping fees for treatment/disposal of contaminated sediments that would be cost-competitive with current upland disposal estimates. However, WDNRs preliminary tipping fee analysis was sensitive to a range of cost assumptions, and so is associated with considerable uncertainty. Nevertheless, because of the stated MTCA and CERCLA preference for permanent treatment remedies, and also because WDNRs estimated costs of a SMURF may be competitive with other off-site disposal options (see below), this option was carried forward in the evaluation of the alternatives. In this case, treatment in a hypothetical SMURF was retained as one of a range of potential off-site treatment and/or disposal process options. Should the off-site treatment and/or disposal option be selected by the Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using such a facility would need to be assessed during remedial design of the Duwamish/Diagonal cleanup project.

7.4.5 In-Water Containment Options

Contaminated sediment may be effectively contained and isolated from potential biological exposure using a range of engineered cap and confined facility technologies. Applying the screening criteria to in-water containment options yields the following results:

In Situ Capping (Thick Layer). This option involves placing a cap, typically composed of a 3-foot-thick layer of clean sand, over the contaminated footprint within the project site. This cap is used to isolate the contaminated sediment from the water column and from the biologically active zone of the sediments. Capping is typically used in relatively low energy aquatic sites, and may also be covered with a protective armor layer in more dynamic systems. As detailed in EPA and USACE guidance documents (Palermo et al. 1998), a cap would be engineered to ensure its effectiveness based on detailed analyses of site hydrodynamics, slope and seismic stability, chemical migration potential, and other factors. These detailed analyses would normally be performed as a component of remedial design. In addition to stability, habitat concerns would also be considered when choosing cap materials.

The available data suggest that prospective capping systems would be stable and effective at the Duwamish/Diagonal site. For example, field observations collected near the site to calibrate the King County hydrodynamic model (King County 1999) revealed maximum near-bottom water velocities of up to approximately 60 cm/s. Based on typical shear strength relationships, a fine sand cap would resist erosion by currents of this magnitude. Potential propeller wash currents must also be considered in cap design. Remedial design studies performed in the Thea Foss Waterway in Tacoma, which has similar water depths and vessel traffic operations as the Lower Duwamish Waterway, indicated that maximum bottom-water velocities resulting from reasonable worst-case vessel operations in that waterway ranged up to approximately 150 cm/s (PIE 1998). At that site, a sediment cap constructed of medium sand particles (more than 30 percent of material larger than 1 mm diameter) would resist erosion, with predicted maximum scour depths of less than 0.1 feet. Similar results are expected at the Duwamish/Diagonal site, and would be verified during remedial design. Clean sand materials (i.e., with chemical concentrations below SQS and Trustee restoration goals) meeting these general grain size specifications are routinely available from maintenance dredging of the upper turning basin of the Duwamish Waterway. Other prospective capping sources are also available.

Due to the presence of the siphon and with potential subsurface sediment contamination extending to elevation -50 feet MLLW in this area, capping portions of the site may be the only feasible solution to isolate contaminants in certain locations. Capping in the federal navigational channel would be subject to the depth constraints necessary to maintain the authorized channel depths. Details of placing a cap near the navigation channel would be worked out in coordination with USACE. Thick layer capping, which may also be used in conjunction with excavation, was retained for further analysis in this evaluation.

In Situ Capping (Thin Layer). This option, which is also referred to as enhanced natural recovery, consists of placing a relatively thin cap, typically composed of clean sand four to eight inches thick, over the contaminated footprint within the project site. In contrast to the complete isolation function of the thick cap discussed above, the thin-layer cap is normally intended to partially mix with the underlying surface sediments, and has been demonstrated at certain sites to be sufficient to achieve cleanup levels throughout the biologically active zone. To the extent that bioturbation processes extend below the bottom of the thin-layer cap, such processes will result in mixing of the clean upper sediments with underlying contaminated sediments. During remedial design, the thickness of the cap is engineered to ensure that cleanup levels are met throughout the biologically active zone, based on site-specific chemical distributions and bioturbation characteristics.

One of the benefits of a thin-layer cap relative to the thick cap discussed above is that there is significantly less short-term loss of existing benthic infauna during construction, as cap placement rates are typically slow enough to allow existing infauna to migrate into and recolonize the new cap surface. Another benefit of thin-layer capping is that it results in less change to existing grades, and thus limits corresponding changes to habitat functions and navigation uses. As above, details of placing a cap near the navigation channel would be worked out in coordination with USACE. The thin-layer cap option has been shown to be effective in achieving cleanup levels at several Puget Sound sites (e.g. Pier 54/55 in Elliott Bay and West Eagle Harbor), particularly in areas where the sediment chemical concentrations are only marginally above cleanup standards. However, thin-layer capping may not be appropriate for prospective navigation or berthing areas, as it provides little or no surface buffer to protect the site from future disturbances associated with maintenance dredging operations. Given that the Duwamish/Diagonal site is located immediately adjacent to a federal navigation channel, and that much of the site area has historically been used for berthing, the thin-layer cap option was not retained for detailed analysis in this evaluation. Nevertheless, if the final remedy for the site were to include sufficient institutional controls for parts of the site to prevent future disturbances, thin-layer capping could potentially be an appropriate process option, and in such a case would be evaluated in more detail during remedial design.

In Situ Capping (Inverted). Inverted capping involves removing the top layer of contaminated sediment and stockpiling on site, then removing enough clean underlying material to be able to place the contaminated material into this deeper excavated area. After the contaminated material is backfilled, the clean sediment is placed on top as a cap. While this process option has been used at certain sites in the U.S., it is rarely utilized in the Northwest. At the Duwamish/Diagonal site, this process option is likely to be impracticable, due in part to the necessary multiple handling of sediment, and the relatively thick deposits of contaminated subsurface sediments that underlie the site, particularly near the siphon. Logistics during construction for this option are significantly more difficult than other capping options due to the dredging and stockpiling component. Therefore, this process option was eliminated from further consideration in this evaluation.

Confined Aquatic Disposal. Confined aquatic disposal (CAD) places dredged contaminated sediment in a submerged location and caps (covers) it with clean material. CADs are designed and placed in locations where they will always be completely underwater. The thickness of the cap and the grain size of the clean sediment are designed to prevent contaminants from migrating back into the aquatic environment. The CAD surface can either be completed as shallow water or deep water habitat, depending on site conditions.

Within the Elliott Bay/Duwamish region, the USACE previously (1984) constructed an experimental 1,000-cy CAD facility within the West Waterway (-40 to -50 ft MLLW), and this site has continued to perform effectively (Sumeri 1996). The U.S. Navy recently completed construction of a somewhat shallower CAD in Sinclair Inlet for containment of contaminated sediment. The USACE has also identified several possible other deep-water CAD locations in the region, including a possible site in the East Waterway, though none of these sites has been formally proposed for construction (Port of Seattle 2000). No prospective CAD location has been identified to date within the immediate vicinity of the Duwamish/Diagonal site. As such, an on-site CAD process option was eliminated from further consideration in this evaluation. However, an off-site CAD could potentially become available in the future, and in such an event would likely be owned, permitted, constructed and operated by an independent third party. Because a prospective future off-site CAD may be cost-competitive with other off-site disposal options, it was retained as one of a range of potential off-site treatment and/or disposal process options. Should the off-site CAD option be selected by the Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using such a facility would need to be assessed during remedial design.

Nearshore Confined Disposal (NCD). This option, otherwise known as a Nearshore Fill, is a type of landfill constructed underwater along the shoreline. A berm is constructed of clean material near the shoreline. The lower layer of the area between the berm and the shoreline is filled with the dredged contaminated sediment. The upper layer is covered with clean sediment or fill material until it is above tidal level. Nearshore fills create new land that can be used for public shoreline access or for businesses that depend on being near water. Since they convert submerged land to dry land, NCDs eliminate aquatic habitat.

NCDs have been constructed and used to contain contaminated sediments at several sites in the Puget Sound region (e.g., Terminal 91 in Seattle, West Eagle Harbor, Milwaukee Waterway in Tacoma), and have continued to perform effectively. Potential NCDs are also being considered for other areas, including two additional sites in Tacoma (Blair Slip 1 and St. Paul Waterway), as well as prospective sites near Harbor Island. Based on an initial screening, there does not appear to be a suitable location on site at which to construct a NCD. As such, an on-site NCD process option was eliminated from further consideration in this evaluation of alternatives. However, an off-site NCD could potentially become available in the future, and in such an event would likely be owned, permitted, constructed and operated by an independent third party. Because a prospective future off-site NCD may be cost-competitive with other off-site disposal options, it was retained as one of a range of potential off-site treatment and/or disposal process options. Should the off-site NCD option be selected by the Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using such a facility would need to be assessed during remedial design.

7.4.6 Upland Disposal

Under this option, contaminated sediments would be dredged and placed in a specially designed landfill that is on dry land, away from surface water. The landfill would include liners and surface water controls to minimize infiltration. A special water collection system would likely also be required so that water draining through the landfill (leachate) does not escape and contaminate local groundwater.

Upland landfill disposal has been used for contaminated sediment remediation at a range of different sites in Puget Sound, including the Panels Norfolk site remediation and the Port of Seattle/USACE Stage I East Waterway cleanup. All of these projects have utilized existing off-site RCRA Subtitle D landfill facilities (e.g., Roosevelt Landfill) that are owned, constructed, permitted, and operated by an independent third party. No upland disposal site or facility has been identified within the immediate vicinity of the Duwamish/Diagonal site.

RCRA Subtitle D Landfills. As discussed above, off-site upland disposal at existing RCRA Subtitle D landfill facilities is a proven technology and relatively straightforward to permit. Depending on disposal quantities, Puget Sound region-specific costs for transport to and disposal at these off-site Subtitle D facilities currently (2001) range from approximately $40 to $55/cy, which are generally comparable to estimated costs associated with some of the other engineered containment options outlined above such as CADs, NCDs and SMURF treatment.

The Duwamish/Diagonal contaminated sediment has been tested for waste characteristics (**Section 4.7.2**). The testing indicates that all of the sediment is non-hazardous and suitable for disposal at a Subtitle D landfill. Two projects implemented in November and December 2001 loaded sediments directly into containers for shipping and offloading at a landfill with a moisture deficit. It is expected that this option is available for Duwamish/Diagonal sediments also. Even were the project subject to a dewatering requirement, the costs associated with dewatering are normally minor in comparison to the stated tipping fees. Based on these considerations, off-site upland disposal is a currently available and likely practicable sediment disposal option. Thus, this option was carried forward.

Construction Reuse/Backfill. A potential alternative to a landfill is to reuse the sediment material as construction backfill, possibly after stabilization of the material to improve its structural qualities. However, substantial evaluation and/or engineering design would likely be required to assure that disposal procedures are safe and that the disposal/reuse site would be effective in containing the contaminated sediment. Concentrations of chemicals may also need to be below relevant MTCA cleanup levels to allow disposal without institutional controls. A preliminary review of the available site characterization data for the Duwamish/Diagonal site indicates that bulk sediment concentrations at the site are greater than those allowable for unrestricted land uses, but may be acceptable at certain controlled industrial site locations. However, this option would likely be relatively difficult to permit and implement (e.g., addressing potential indemnification issues), and may not be substantially more cost-effective than off-site upland disposal. Based on the above reasons, this option was eliminated from further consideration.

7.4.7 Summary of Retained Technologies And Process Options

A summary of the screening of technologies and process options is presented in Table 7.2. Where practicable, a permanent cleanup remedy is clearly preferred under both MTCA and CERCLA, and the inclusion of a range of removal and treatment/disposal process options in this evaluation of alternatives would be consistent with the intent of these regulations.

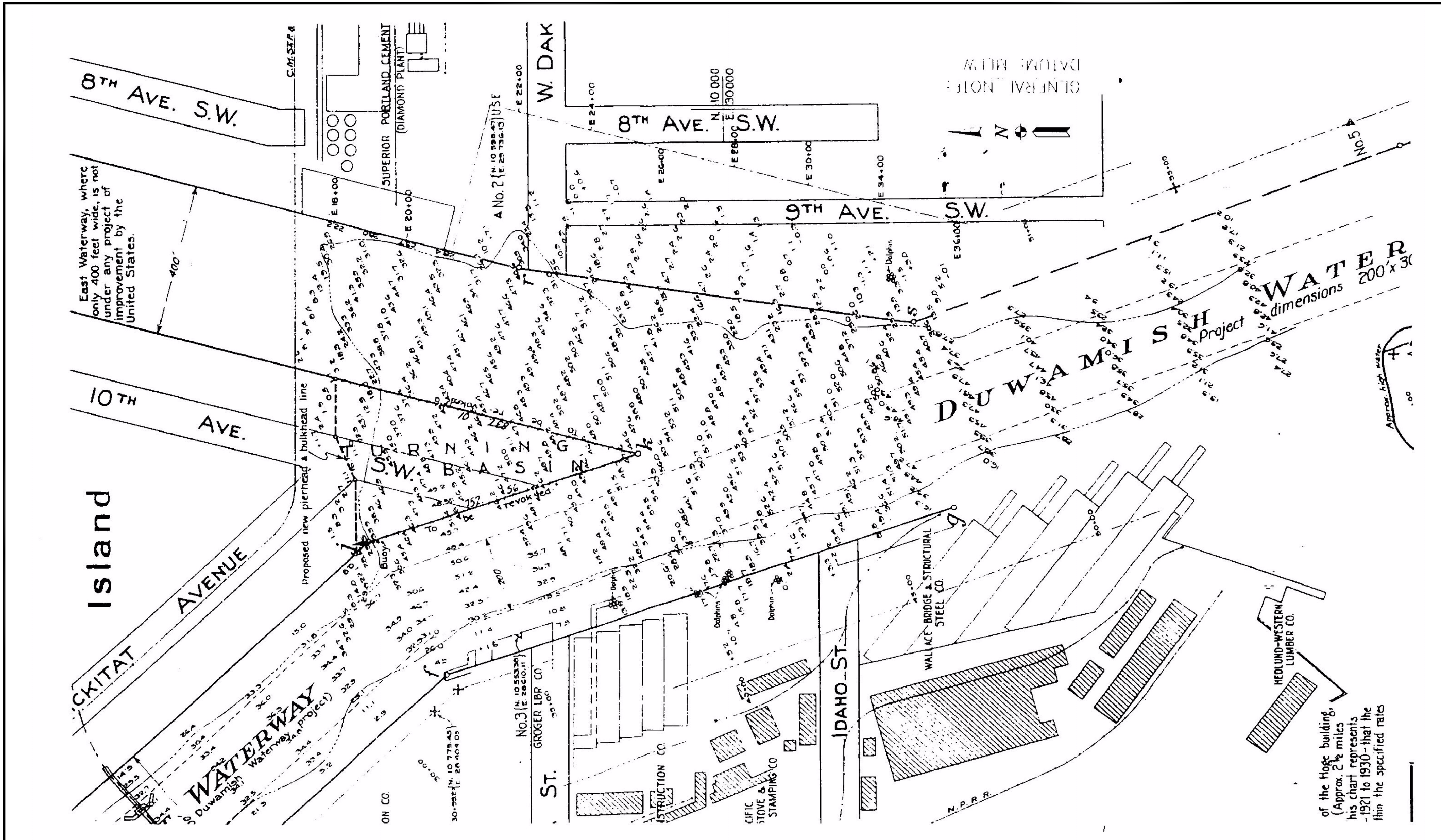
There are several reasons why permanent solutions, as defined under the MTCA and CERCLA regulations, may not be practicable for application throughout the Duwamish/Diagonal site. For example, previous construction of the sewer siphon required excavation of a trench through the center of the site to an elevation of at least -50 feet MLLW. The area affected by trench excavation was backfilled, resulting in potential contamination to the bottom of the trench. Also, cores collected and analyzed during the site assessment, particularly those located near shore, indicated contamination (exceedance of SQS chemical criteria) extending at least six feet below the existing surface elevations. It is not known how deep contamination extends in these areas. Extended depths of dredging near shore may also cause significant slope failure along the riprapped shoreline slopes. Because of the above reasons, complete removal of all contaminated sediment is probably not achievable. Some areas within the site potentially can be excavated to remove all contaminated sediment while other areas will require capping to isolate the contaminated sediment.

All disposal options that have been retained as a result of the initial screening process involve off-site facilities that would be constructed by other parties. The Duwamish/Diagonal sediment would be taken to one of these facilities and a tipping fee would be paid to an independent vendor to handle the sediments, potentially also including an indemnification provided by the vendor accepting future liability associated with these materials. No permitting or construction of the disposal site would be required by the Duwamish/Diagonal project. Each of the retained off-site disposal options, (CAD, NCD, upland landfill, and SMURF) have costs that have been estimated by various parties such as WDNR and USACE as within the same general range (within the uncertainties about the specific site or location). Therefore, for the remainder of this report, all disposal options will be considered as similar and will be represented by disposal at a Subtitle D landfill (e.g., Rabanco's Roosevelt Landfill in Klickitat County, Washington), in part because this technology is the only option that is currently available, and thus has more certainty than the other disposal process options. However, should the off-site disposal or treatment option be selected by the Panel as part of an overall cleanup remedy for the Duwamish/Diagonal site, the availability and cost of using alternative, prospective CAD, NCD, upland landfill, or SMURF facilities would need to be reassessed during remedial design.

Table 7.2 SUMMARY OF SCREENING OF TECHNOLOGIES AND PROCESS OPTIONS

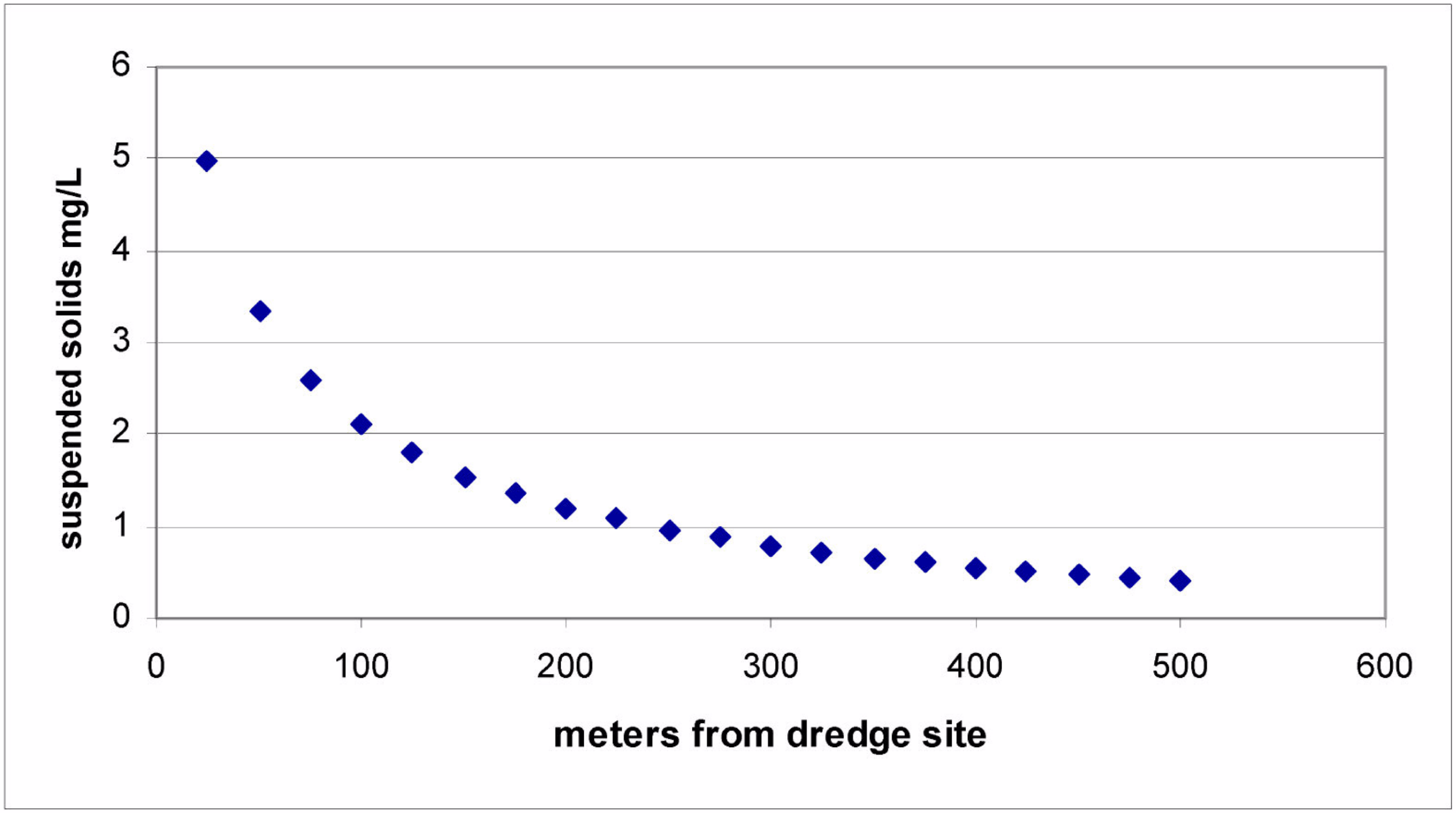
Options	Technical Effectiveness (Does the option appear to have merit?)	Implementability (Is the option feasible?)		Relative Cost (low, medium, high)	Adverse Impacts (Does the option have significant adverse impacts?)	Comments	Carried Forward
		Logistics	Regulatory				
No action•	No.•	Yes.•	No.	Low• • •	Not beyond current levels.	This option is carried forward as a basis for alternatives comparison	Yes
Natural Recovery	No.	Yes.	No.	Low	Not beyond current levels.	Eliminated as remedial option.	No
Mechanical Dredging	Yes. Proven technology.	Yes. Dredging would probably be barge based.	Yes. Proven technology.	Medium	No. Dredging will suspend some sediment in the water column, but this is short term and limited.	Due to contamination associated with the sewer siphon that cannot be removed easily, this option is combined with capping.	Yes
Hydraulic dredging	Yes. Proven technology, small volumes result in higher unit costs.	Only if dewatering with direct discharge is allowable.	Yes. Proven technology.	Medium	No. Dredging will suspend some sediment in the water column, but this is short term and limited.	Hydraulic dredging has higher costs and is more complicated to plan and permit than mechanical dredging; therefore it is eliminated.	No
SMURF• • • • •	Yes, if one were available.	Yes, if a facility is set up by other entities at offsite location.•	Would be handled by facility sponsors.•	Medium	None at D/D site.	No facility currently available.	Yes, if a facility is developed
In situ thick cap	Yes.	Yes, if in conjunction with excavation in area adjacent to navigational channel.	Yes, if in conjunction with excavation in area adjacent to navigational channel.	Medium	No.	If not done in conjunction with excavation, there may be conflicts with navigational and fishing rights.	Yes
In situ thin cap	No, due to near- by navigational uses.	Yes.	Unknown. Concerns about effectiveness	Low	No.	Eliminated.	No

Options	Technical Effectiveness (Does the option appear to have merit?)	Implementability (Is the option feasible?)		Relative Cost (low, medium, high)	Adverse Impacts (Does the option have significant adverse impacts?)	Comments	Carried Forward
		Logistics	Regulatory				
In situ inverted cap	Not for this site.	Impractical due to the great depth to clean sediment and the presence of the siphon	Unknown. Little track record in region.	High	No.	Eliminated.	No
Confined Aquatic Disposal	Yes, if available.•	No locations readily available.	No. CAD sites in Elliott Bay are difficult to permit.	High	None at D/D site.	No facility currently available.	Yes, if a facility is developed
Nearshore Confined Disposal	Yes, if available.	Only if a nearshore development project is available in the necessary time frame.	Would be handled by development sponsors.	Medium	None at D/D site. Disposal site would have issues of nearshore habitat and fishing.	No facility currently available.	Yes, if a facility is developed
RCRA Subtitle D Landfill	Yes.•	Yes.•	Yes, the material has been tested and found to be non-hazardous.	Medium	No.	Would be required to pass paint filter test at point of loading.	Yes
Miscellaneous Upland Disposal Locations	Unknown.	No. •	No.	Unknown (project specific).	Unknown (project specific).	No sites are currently identified. Eliminated due to unknowns.•	No
Construction Backfill	Yes, provided site specific criteria are met	No, project specific analyses required.	No, process would be difficult.	Unknown (project specific).	Unknown (project specific)	No sites are currently identified. Eliminated due to unknowns.	No



EcoChem Team	Duwamish/Diagonal Sediment Remediation Project 1931 Condition Survey USACE	Figure 7-1

12/19/01 DWD008-01 00-086-01

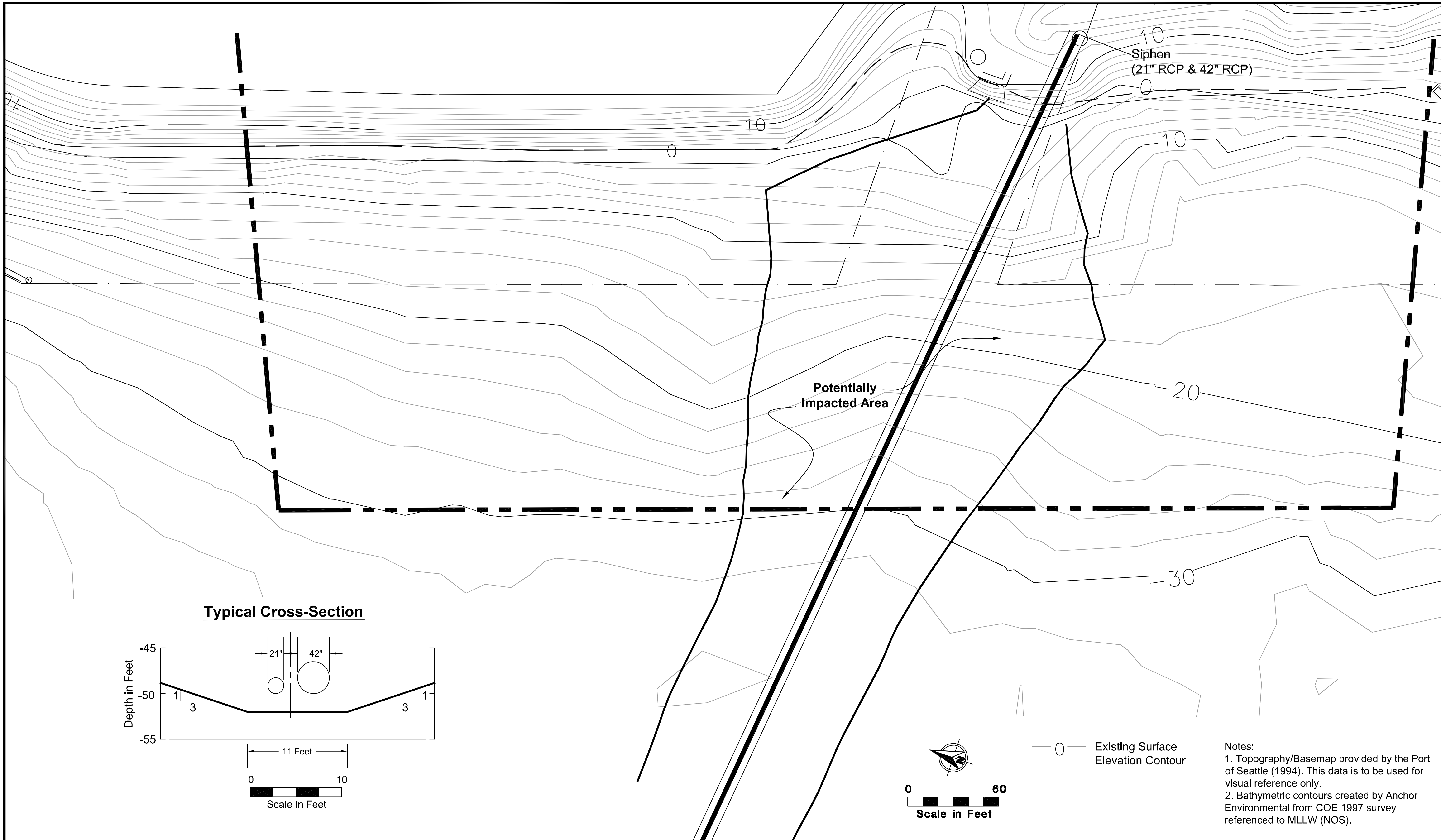


EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Suspended Sediments Predicted by Dredge at
8m Below the Water Surface

Figure 7-4



Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).

00-086-01

DWD011-01

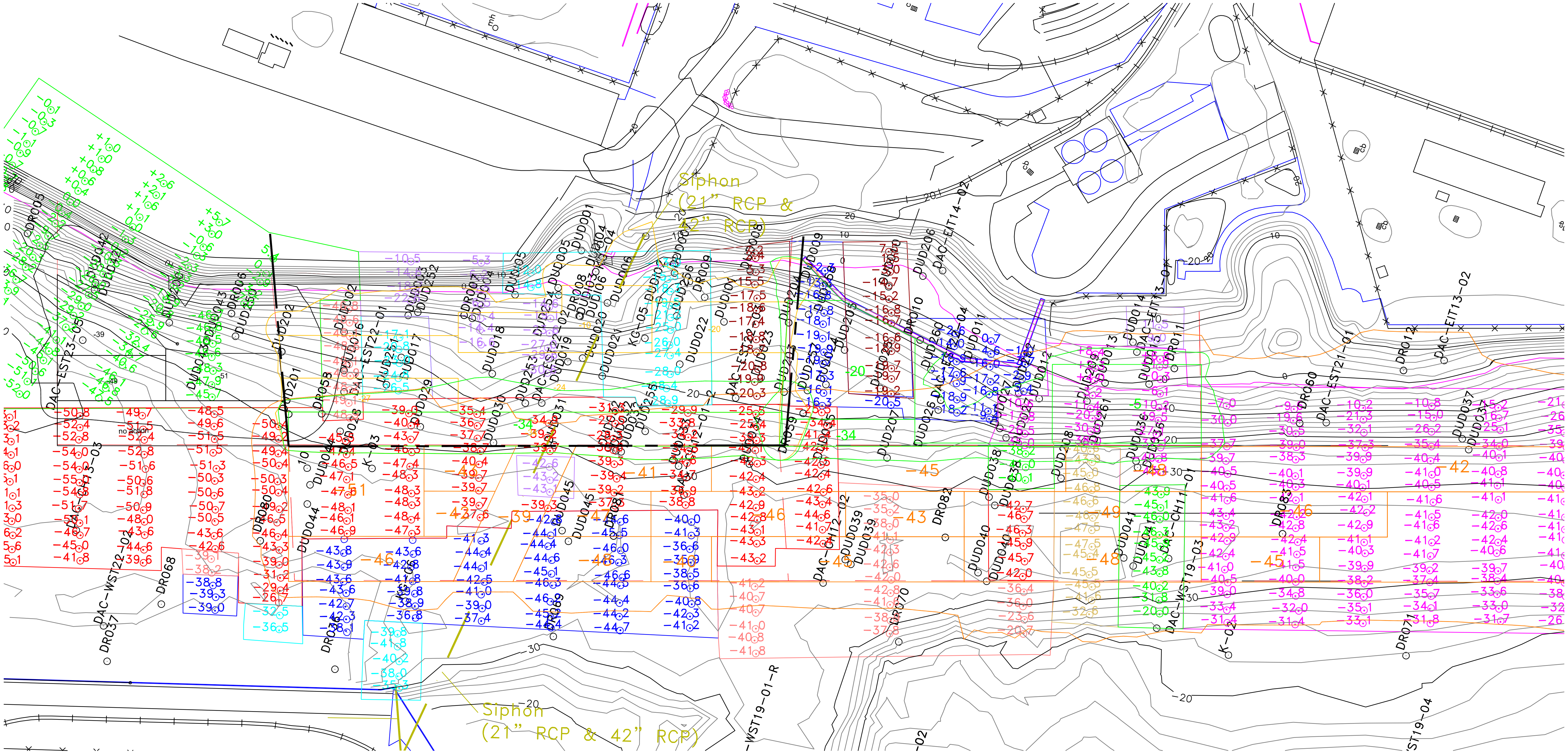
12/19/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Estimated Disturbed Sediment Boundary during Construction of Siphon

Figure 7-3



Historic Dredge Dates	
-43.3	1925
-41.6	1928
-43.8	1932
-40.6	1943
-41.0	1950
-43.2	1968
-28.9	1970
-17.5	1978
-17.2	1984

Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).

0 150
Scale in Feet

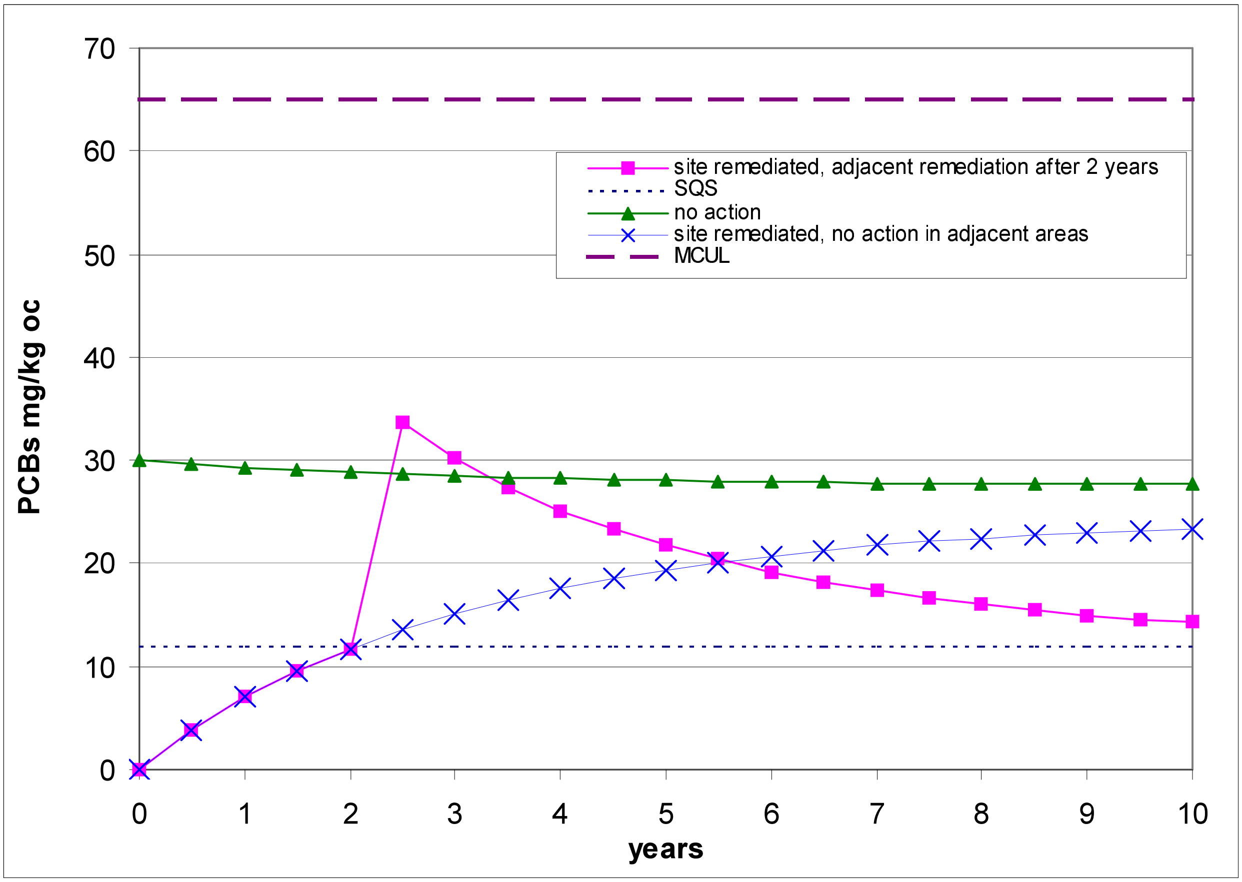
EcoChem Team

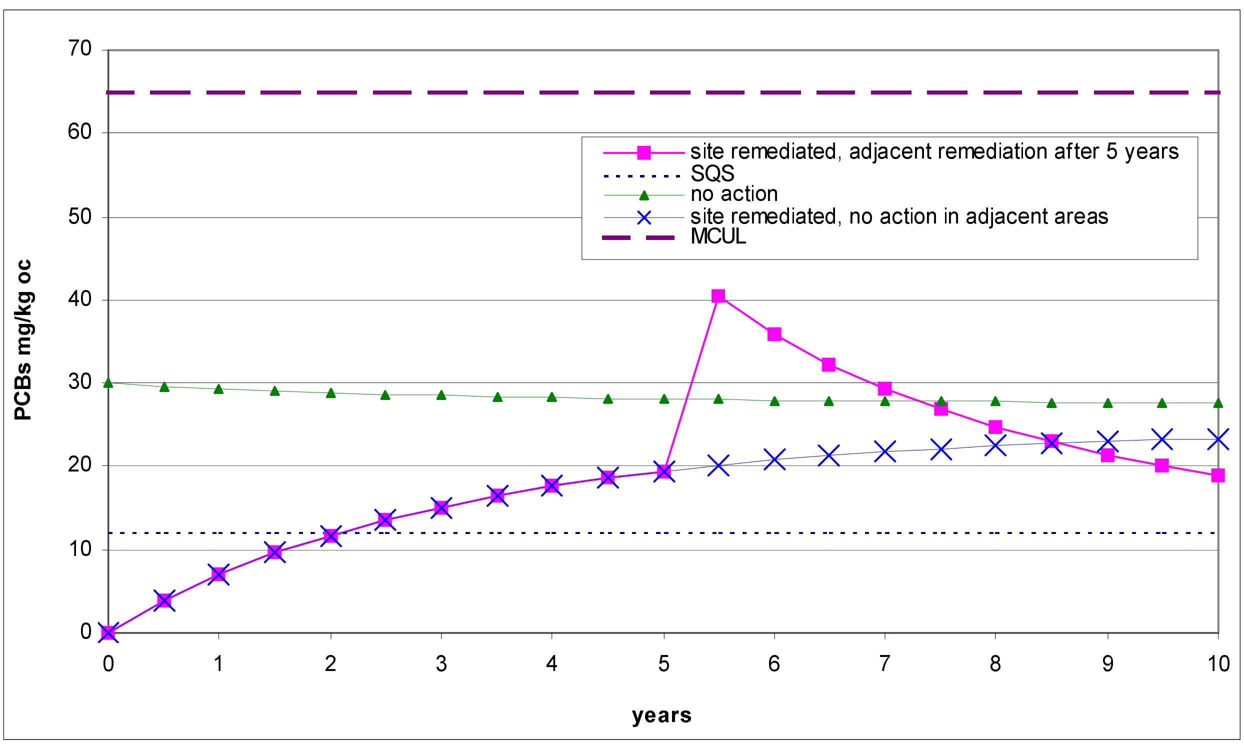
Duwamish/Diagonal Sediment Remediation Project

Deepest Historical Dredge Depths

Figure 7-2

00-086-01
DWD004-01
12/19/01





EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 7-5
	Natural Recovery Model Results	

00-086-01
DWD010-01
12/19/01

8 SCREENING AND DEVELOPMENT OF ALTERNATIVES

Following initial screening, the technology types and process options retained for screening and development of alternatives are:

- No Action
- Excavation
  - Mechanical Dredging
- In-Water Containment
  - Thick Layer In Situ Capping
- Off-site Disposal (representative of a range of off-site disposal and treatment options)

The objective of this chapter is to assemble, screen, and develop alternatives that will undergo more detailed evaluation in a subsequent section of this Report. These alternatives were assembled from potential combinations of the technologies and process options that were retained following the initial screening in **Chapter 7**. After the alternatives were assembled, a secondary screening was applied based on further considerations of technical effectiveness, implementability, cost, and adverse impacts. A conceptual design of each alternative was then developed, and served as the basis for the more detailed evaluation presented in **Chapter 9**.

8.1 ASSEMBLY OF ALTERNATIVES

Utilizing the above technology and process options, the following preliminary alternatives were assembled to represent a broad range of potential response actions at the Duwamish/Diagonal site:

- Alternative 1: No Action. This alternative, which would entail leaving the site as-is with no further action, is carried forward as a baseline for comparison with the other alternatives.

- Alternative 2: Maximum Practicable Containment. The overall objective of this alternative is to achieve SQS chemical criteria throughout the cleanup site while maintaining existing navigation channels and shoreline structures, and minimizing dredging and disposal of contaminated sediment. The focus of this alternative is minimizing dredging and disposal volumes. This alternative does not accommodate the objectives of maintaining existing habitat elevations and removing possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas. Alternative 2 would combine minimal dredging near the navigation channel and near certain shoreline structures (to accommodate cap backfill), off-site disposal of all dredged materials, and capping the entire site with a clean sand cap designed and constructed in accordance with EPA and USACE standards, in order to ensure its long-term integrity and performance. Upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action.

- Alternative 3: Capping with No Change in Existing Elevations. The overall objective of this alternative is to achieve SQS chemical criteria throughout the cleanup site while maintaining existing depths and elevations throughout the site, concurrently minimizing dredging and disposal of contaminated sediment to the extent practicable. In this alternative, maintaining existing habitat elevations predominates over competing objectives of minimizing dredging and disposal volumes and removing possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas. Alternative 3 would achieve this objective through a combination of dredging of a surface layer throughout the site (approximately 3 feet) to accommodate cap backfill, off-site disposal of all dredged materials, and capping the entire site with a clean sand cap designed and constructed in accordance with EPA and USACE standards, in order to ensure its long-term integrity and performance. Upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action.

- Alternative 4: Maximum Practicable Removal of Contaminants. The overall objective of this alternative is to achieve SQS chemical criteria throughout the cleanup site while allowing for maximum practicable flexibility in future deepening of the navigation channels, without the risk of exposing or excavating contaminated sediments in the future. In this alternative, removing possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas predominates over a competing objective of minimizing dredging and disposal volumes. In addition, the objective of maintaining existing habitat elevations could be achieved by backfilling the excavations with clean material. Alternative 4 would be implemented through a combination of dredging sediments to the maximum practicable extent (excluding within the siphon area), off-site disposal of all dredged materials, capping relatively limited areas of the site such as the siphon where subsurface contaminated sediments will remain in place, and backfilling as necessary. As in Alternatives 2 and 3, upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action.

8.2 SCREENING OF ALTERNATIVES

The individual handling, treatment, and disposal options components were screened in **Section 7.4** in order to eliminate those technologies and/or process options not considered feasible. The next step is to evaluate the assembled alternatives against each other with respect to the screening criteria below:

- Technical effectiveness.
- Implementability.
- Cost effectiveness.
- Adverse impacts.

8.2.1 Alternative 1: No Action

Alternative 1 would not implement any remedial actions. The site would remain as is and no institutional controls would be implemented. As discussed above, this alternative was carried forward as a basis for comparison.

8.2.2 Alternative 2: Maximum Practicable Containment

This alternative would clean up the site by placing a thick cap of clean material over the contaminants and isolating them from the environment. Dredging is required in the areas (1) near the navigation channel to ensure that the cap does not encroach on the channel and reduce the minimum authorized water depths and (2) in front of the outfall so the cap does not impede discharge flows.

Thick layer capping is an effective technology that is proven and has been accepted on several projects in Puget Sound and Elliott Bay. Permitting for this alternative is relatively straightforward and similar to the other cleanup alternatives. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these would include anchoring, dragging, digging, and pile driving without proper conditions. However, there are two issues that might slow the permitting process. First, the potential Tribal fishing issues and alteration of habitat type might raise concerns. Second, the level of detail required by the agencies for review may be greater than for dredging options due to concerns for cap stability.

Evaluation of site characteristics, including flow velocity and existing sediment grain size, will need to be taken into consideration in design of a cap to ensure its stability. In addition to stability, habitat concerns would also be considered when choosing cap materials.

Disposal of excavated material is a significant cost, so minimization of dredged volumes that this alternative offers also minimizes the overall cost of cleanup. The cost of disposal at an upland Subtitle D landfill has been declining over the last several years at the major regional landfills such as Roosevelt Landfill in Klickitat County, Washington and Columbia Ridge Landfill in Arlington, Oregon. Currently the general quoted cost range is between $28 and $34 per ton (equivalent to approximately $40 to $55/cy, including transportation) depending on the quantity required. The sediments would need to be rehandled out of the haul barge and placed at an upland rehandling site where they would be loaded into trucks or rail cars for transport to the disposal facility.

The project site is located outside of the Corps of Engineers navigation channel limits and there are no present navigation requirements within the site. However, the Port of Seattle - the current site owner may in the future identify navigational requirements at the site, which could potentially conflict with a cap. In addition, a 3-foot-thick cap in the area in front of the E shaped pier could impact navigational access to this pier. The mudline elevation in this area is currently at approximately -20 feet MLLW. A study of potential navigational needs of E-pier users was not performed as a part of this report. Placing a 3-foot cap over the site would also reduce water depths and potentially the width of the channel, which could have an impact on tribal fishing activities, and would also alter the quality and function of existing habitat (converting some subtidal habitat to intertidal habitat). However, since these potential impacts are not atypical of other sediment capping projects implemented in the Puget Sound region, this alternative was carried forward for detailed evaluation.

8.2.3 Alternative 3: Capping with No Change in Existing Elevations

This alternative would clean up the site by removing a layer of contaminated material throughout the site and capping the remaining surface with clean material to return the site nominally to existing elevations. The cap would be designed to isolate the remaining subsurface sediment contamination from the environment. Similar to Alternative 2, Alternative 3 employs proven and accepted remedial technologies. Permitting for this alternative is also relatively straightforward and similar to the other cleanup alternatives. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these would include anchoring, dragging, digging, and pile driving without proper conditions. Evaluation of site characteristics, including flow velocity and existing sediment grain size, will need to be taken into consideration in the design of a cap, as discussed under Alternative 2.

Since a cap probably would be placed using mechanical equipment, the dredging equipment could be utilized for construction of a cap, thereby saving mobilization costs. Disposal costs are discussed under Alternative 2. Again, since potential impacts associated with implementation of Alternative 3 are not atypical of other sediment cleanup projects implemented in the Puget Sound region, this alternative was carried forward for detailed evaluation.

8.2.4 Alternative 4: Maximum Practicable Removal of Contaminants

This alternative includes the maximum practicable removal of contaminated sediments by dredging and off-site disposal. For the purpose of development of this alternative, the vertical extent of sediment contamination was defined based on the deepest historical dredge depths recorded by the USACE in this area. Maximum practicable removal would allow the site to be used for a wider range of potential future uses, while minimizing future encumbrances. The sediments would likely be dredged with a mechanical clamshell dredge, loaded into a haul barge, and taken to an approved disposal site. Disposal sites are discussed in Alternative 2. Dredging activities in the vicinity of the two buried siphon lines would have to be carefully designed to ensure that the siphons are not damaged. The site would then be backfilled as necessary with clean sand to restore existing aquatic habitat elevations. In the vicinity of the siphons this backfill will be an environmental cap that would include appropriate design (e.g., grain size specification) to ensure its long-term integrity and performance. There would be no future use limitations or institutional controls placed on the majority of the site, since all contaminants would be removed-with the exception of those associated with the area over the siphon.

Alternative 4 employs proven and accepted technologies. Permitting for this alternative would be relatively straightforward and similar to the other cleanup alternatives. Again, since potential impacts associated with implementation of Alternative 4 are not atypical of other sediment cleanup projects implemented in the Puget Sound region, this alternative was carried forward for detailed evaluation.

8.3 DEVELOPMENT OF ALTERNATIVES

Based on the above analysis, Alternatives 1, 2, 3, and 4 are carried forward for further detailed evaluation. Alternative 1 (No Action) is carried forward only for the purpose of providing a baseline comparison.

To prepare a detailed evaluation, it was first necessary to provide a conceptual design for purposes of evaluation and comparison against other alternatives. In the absence of sufficient design-level information and data, the conceptual design must necessarily rely on assumptions for certain parameters. Key areas requiring assumptions included: (1) the assumed location of an upland staging area(s); (2) source of cap and backfill materials; (3) agency agreement on cleanup levels (**Section 6.2**) and future recontamination risks (**Section 7.3**); and (4) specific permitting requirements applied to the cleanup actions (**Section 6.1**). For this analysis, we have assumed the following:

- <u>Upland sites within the Duwamish Waterway will be available for use as staging areas and rehandling areas</u>. Dredged material typically is placed into haul barges, which require an upland transfer site to offload either into trucks or rail cars for transport to the final disposal location. The former LaFarge property, located adjacent to the site at Terminal 108, is currently vacant and is advertised for lease by the Port. This property is 7.2 acres in size, including 5.1 acres of uplands and 2.1 acres of submerged property. An existing rail spur is at the site, though it is unclear if there is sufficient room to queue or load rail cars for transporting to the landfill, or dewatering activities, if required. The E shaped pier has electrical power and was previously used with a conveyor system to transfer cement from barges to the LaFarge facility. This conveyor system is no longer present but a similar system could be installed. Rabanco utilizes the former Crowley dock facility on Harbor Island to offload barges and load their rail cars for transport to their landfill in Roosevelt, Washington. This property is also owned by the Port and is expected to be available. For this analysis, it was assumed that the former LaFarge property would not be used (because it may not be available) and that the Crowley facilities would be utilized to off load the barges.
- <u>Availability of sufficient quantity of clean capping material</u>. The traditional source of capping material in the Duwamish River and Elliott Bay areas has been sands from the bi-annual dredging of the turning basin at the southern end of the Duwamish Waterway. Typically, the USACE dredges 100,000 cy of material during each of these events. Demand for these sands is increasing as more projects are proposed; however, a substantial proportion of these materials is still available even for the upcoming (2001/2002) dredging project (H. Arden, USACE, personal communication). However, it is not certain that a sufficient quantity of sands with the necessary specifications (grain size and chemical quality) would be available from the turning basin at the time the project is

undertaken. Therefore, cost estimates developed for this evaluation used the conservative assumption that capping material would be purchased and delivered from an upland quarry. It is possible, and even likely, that suitable capping material would be available from the turning basin and the total cost would be reduced appropriately.

- Cleanup standards and recontamination risk. We have assumed that the prospective cleanup standards for this remedial action are the SQS chemical criteria, and that the future risk of site recontamination can be acceptably managed through the implementation of upland source controls and appropriate coordination with cleanup of the adjacent waterway. Based on the preliminary recontamination modeling presented in **Section 7.3** and **Appendix P**, if cleanup of adjacent sediment areas is accomplished with approximately 5 years following the Duwamish/Diagonal remedial action, the risk of recontamination may be acceptably small.
- Acceptance that future development actions may affect the site. For example, potential future redevelopment activities by the Port of Seattle or channel widening and deepening projects by the USACE, could require additional cleanup and remediation in the future.

8.3.1 Alternative 1: No Action

Under this alternative, no remedial action would occur. The site would remain as is. No institutional controls would be implemented and no long-term monitoring would occur. Monitoring of the Diagonal CSO outfall as required for NPDES permits or other programs would occur as normal. This alternative is carried forward for comparative purposes.

8.3.2 Alternative 2: Maximum Practicable Containment

Capping is typically accomplished using mechanical methods. For marine aquatic sites, a typical method is to position a bottom dump barge loaded with capping material (i.e., typically sand) over the site and then slowly open the barge doors as the barge is towed across a portion of the site to deposit the cap material with minimum disturbance. The falling material covers the site at that location and the barge is repositioned during the next discharge activity. If greater control during cap placement is required, the capping material can be offloaded from a flat deck or haul barge with dozer or front end loader, or rehandled onto the site directly by crane with a bucket. Another mechanical option includes using a conveyor system to transport the capping material to the site. It is anticipated that capping equipment will be located on the water due to limited access to the site from the shore. Because of the nearshore slopes at the site, it is also anticipated that any capping activity on the nearshore slope would be performed using a crane and bucket to rehandle the capping material from a floating barge directly onto the site. Rehandling the material increases the construction cost but provides tighter control of the cap depth and extent.

Capping material can be obtained from USACE maintenance dredging activities in the turning basin of the Duwamish River or other Puget Sound regions, or material potentially could be imported from an upland sand and gravel facility. Obtaining capping material from other dredging projects would require logistical coordination between projects. Capping on the existing slope will require that the post construction cap slope be no steeper than approximately 3H:1V due to the angle of natural repose of the capping material (**Figures 8-1** and **8-2**). Cap material on the existing intertidal slope would probably consist of a select mix of sand and gravel, and, if determined necessary during the design phase of this project, cobble sized material for cap stability and slope stability issues. Because existing sediment classification ranges from sandy silts to silty sands with more sand towards the shore, a select mixture with coarser material will protect against cap erosion better than using similarly graded material as in situ. The preliminary volume of capping material needed for Alternative 2 is 22,000 cy (33,000 tons), based on a minimum 3-foot cap with 3H:1V nearshore slope.

Estuarine caps are subjected to dynamic forces and can potentially shift to a more stable configuration. The cap design would anticipate this condition. Future monitoring including condition surveys would be performed to verify the long-term stability and integrity of the cap and whether any maintenance of the cap would be necessary.

A thick cap would isolate any contamination from the environment and would generally raise the elevation of the site under this alternative by three feet, thereby increasing the area of shallow subtidal, low intertidal, and high intertidal habitat zones.

The area immediately adjacent to the navigation channel would need to be dredged so that there would be minimal encumbrances on future USACE maintenance needs. The navigation channel has an authorized depth of -30 feet MLLW. Sediments would be removed to an elevation of -35 feet, resulting in approximately 9,000 cy (13,500 tons). Then a 3-foot cap would be placed over this area and the entire site. This will allow the normal 2-foot tolerance (i.e., overdepth allowance and/or advance maintenance depth) between the authorized depth of the navigation channel and the top of the environmental cap. Similarly, approximately 500 cy would be removed near the outfalls to allow a 3-foot cap that would not interfere with discharge flows. The existing rip-rapped bank would have a dressing of armor stone and fish mix placed on it (approximately 1,700 cy [2,500 tons]).

The sediments would likely be dredged with an 8 to 12 cy mechanical clamshell dredge bucket, loaded into a haul barge, and taken to an offloading and rehandling site. As discussed earlier, Rabanco's Roosevelt Landfill is used as a representative disposal facility for this evaluation. The haul barge would be moved using a tugboat. The dredged material could be dewatered directly on the barge or dewatering could occur on the upland site, if necessary. Rabanco would offload the sediments at the Crowley dock on Harbor Island, place them in a lined container and transport them to the landfill.

As Rabanco's landfill has a moisture deficit, dewatering is not anticipated. If dewatering were required, it could occur on the barge or at an upland facility. If dewatering were to occur on the barge only, free water would be discharged through a filter system to reduce or eliminate suspended solids. If more extensive dewatering were necessary, an upland dewatering area could be constructed. This area typically includes construction of a diked area, with retaining berms or other structures to prevent the loss of contaminated sediment off site. The area may need to be lined to address groundwater contamination concerns. Since there is a relatively high percentage of coarse sediment (i.e., sand) within the dredge area, more complicated and expensive dewatering methods (e.g., presses and centrifuges) are not expected to be required.

The construction monitoring plan for dredging would include impacts to water quality and Tribal fishing.

Based on the recontamination modeling performed on the Duwamish outfall and discussed in **Section 8.4**, it appears that the cap could become recontaminated by phthalates in the vicinity of the Duwamish/Diagonal outfalls if upland source controls are not implemented prior to initiation of this remedial action. In the absence of complete source control, it is possible that a sediment impact zone, as allowed for under the SMS, would be required. The size and duration of the impact zone would be determined during the design phase of the project using the methods described in WAC 173-204-590.

The recontamination analysis for dredging adjacent locations, discussed in **Section 7.3**, indicated that adjacent sites may recontaminate the Duwamish/Diagonal site with PCBs to a level greater than the SQS (but less than the MCUL), if cleanup of these areas is not appropriately coordinated. If this recontamination occurs, one mitigation measure that could be required by the regulatory agencies would be for the sponsor of the adjacent project to place an additional thin-cap layer (e.g., 0.5-feet-thick) over the Duwamish/Diagonal site to reduce contaminant levels at the site to below the SQS. Alternative approaches may also be appropriate.

Institutional controls would also need to be included with this alternative to ensure the future integrity of the cap (e.g., limitations on anchoring, dredging, and construction).

8.3.3 Alternative 3: Capping with No Change in Existing Elevations

This alternative includes dredging a minimal amount of contaminated material and capping the site back to existing elevations with clean sands and other materials required to ensure stability (**Figures 8-3** and **8-4**). This would allow for all existing site uses to continue or any future site uses to be performed under the current conditions. In addition, all the existing habitat elevations would remain intact. The sediments would likely be dredged with a mechanical clamshell dredge (8 to 12 cy bucket), loaded into a haul barge and taken to an approved disposal site. Disposal sites are discussed in Alternative 2. The precise design of the isolation cap will be determined during the design phase of the project, but it is expected that it will be a minimum of approximately 3 feet thick. The minimum 3-foot cut in this area is estimated to be approximately 42,500 cy (63,750 tons). Due to construction limitations of working on a slope, this translates to an average cut of 5.3 feet across the site. As in Alternative 2, this alternative includes advance maintenance dredging at the channel boundary to allow the cap to remain two feet below the USACE 30-foot channel depth. Institutional controls would be included with this alternative to ensure the future integrity of the cap.

Mechanical dredging would be accomplished using a clamshell dredge from a floating barge. Dredging can also take place using a crane with clamshell from the shore if the crane has sufficient reach to dredge the sediment. For this site, the area to be dredged is located on the east side of the Duwamish River, and has limited access from shore. Therefore, dredging would be most effective from a floating barge. A haul barge would be tied up next to the mechanical dredge barge and will be used to transport the dredged material to the upland rehandling site, as discussed in **Section 8.3.2**.

The toe of dredging near the shoreline will be set back sufficient distance to avoid undermining the existing slope. A slope of 3H:1V has been used for external side slopes and 2H:1V for internal slopes, due to the depth of the cuts (**Figure 8-4**). The minimum 3-foot cut in this area is estimated to be approximately 42,500 cy (63,750 tons). **Section 8.3.2** discusses the thick layer cap technology including material type, sources, and techniques for placement. The preliminary volume of capping material needed to return the site to original grade is approximately 42,500 cy (63,750 tons). The existing rip-rapped bank would have a dressing of armor stone with fish mix placed on it (approximately 1,700 cy [2,500 tons]) to ensure the long-term stability of the slope and create a more fish-friendly slope.

Sediment recontamination risks and contingency measures would be as generally described for Alternative 2.

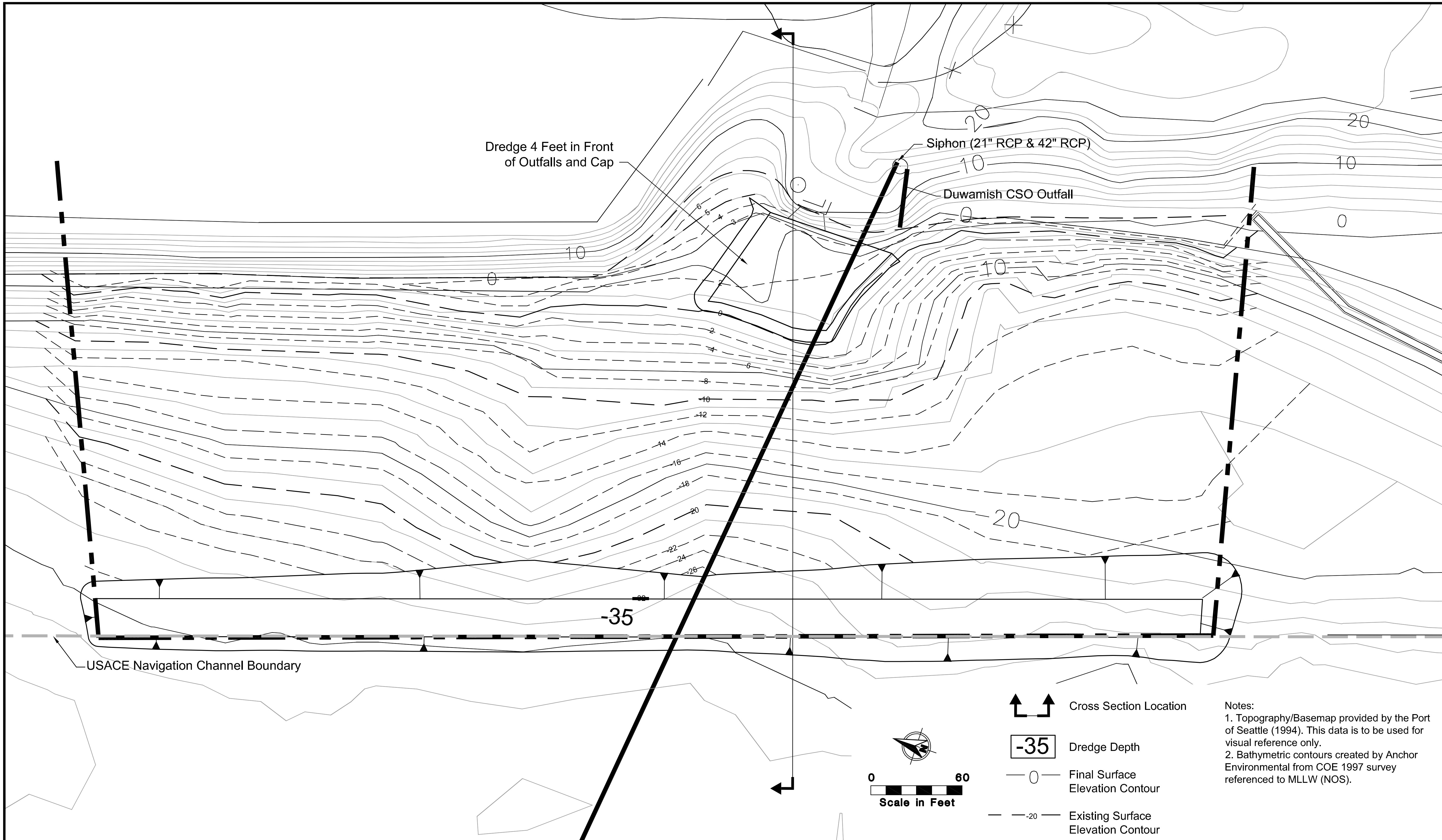
8.3.4 Alternative 4: Maximum Practicable Removal of Contaminants

This alternative includes removal of the maximum amount of contaminated sediments practicable by dredging to historical dredge depths (**Figures 8-5** and **8-6**). Not all contaminated sediments can be removed in the vicinity of the siphons. This will allow the site to be used for any future use with minimal future encumbrances. This alternative will likely involve the removal of approximately 82,000 cy (123,000 tons) of contaminated sediments. The sediments would likely be dredged with a mechanical clamshell dredge (8 to 12 cy bucket), loaded into a haul barge, and taken to an approved disposal site. Disposal sites are discussed in Alternative 2 (**Section 8.3.2**).

Dredging activities in the vicinity of the two buried siphon lines would be carefully designed to ensure that the siphons are not damaged. The site would then be backfilled with clean sand to restore the elevations for valuable habitat. However, in the vicinity of the siphons this backfill will be an environmental cap and would need to include appropriate grain size to prevent erosion. By leaving a minimum of five feet of cover over the siphons during dredging activities and capping with clean material back to existing grade, the siphons will have a 10- to 15-foot thick clean cap (15 to 20 feet total) over it. **Section 8.3.2** discusses the thick layer cap technology including material type, sources, and techniques for placement. The preliminary volume of capping and backfill material needed to return the site to original grade is approximately 82,000 cy (123,000 tons). The existing rip-rapped bank would have a dressing of armor stone and fish mix placed on it (approximately 1,700 cy [2,500 tons]). There would be no future use limitations or institutional controls placed on the site except in the vicinity of the siphons, since all contaminants would be removed.

The toe of dredging near the shoreline will be set back sufficient distance to avoid undermining the existing slope. A slope of 3H:1V has been used for external side slopes and a slope of 2H:1V has been used for internal slopes due to the depth of the cuts (**Figure 8-6**).

Sediment recontamination risks and contingency measures would be as generally described for Alternative 2.



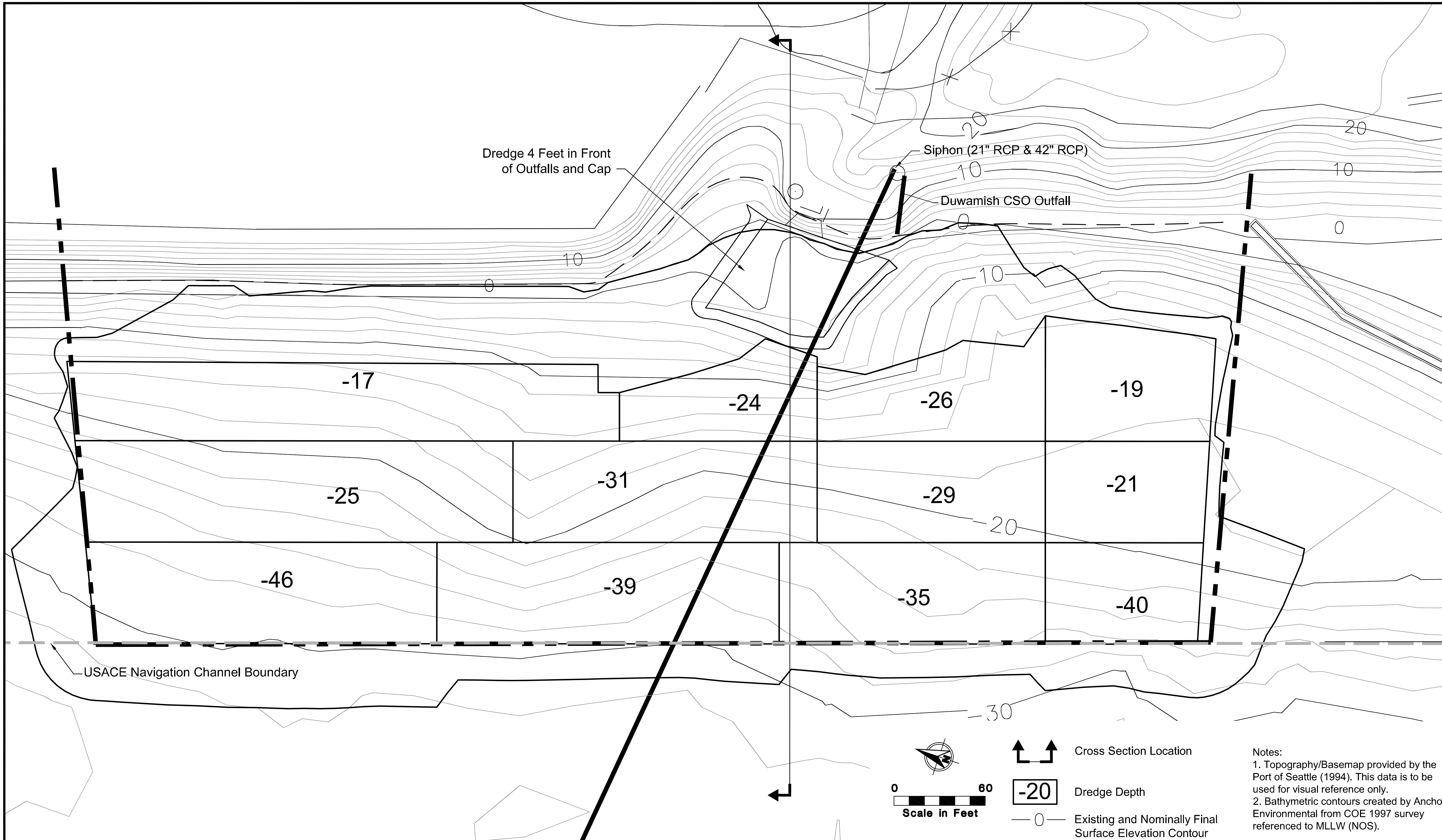
Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).

00-086-01

DWD006-01

12/19/01

EcoChem Team	Duwamish/Diagonal Sediment Remediation Project	Figure 8-1
	Alternative 2: Maximum Practicable Containment (Plan View)	



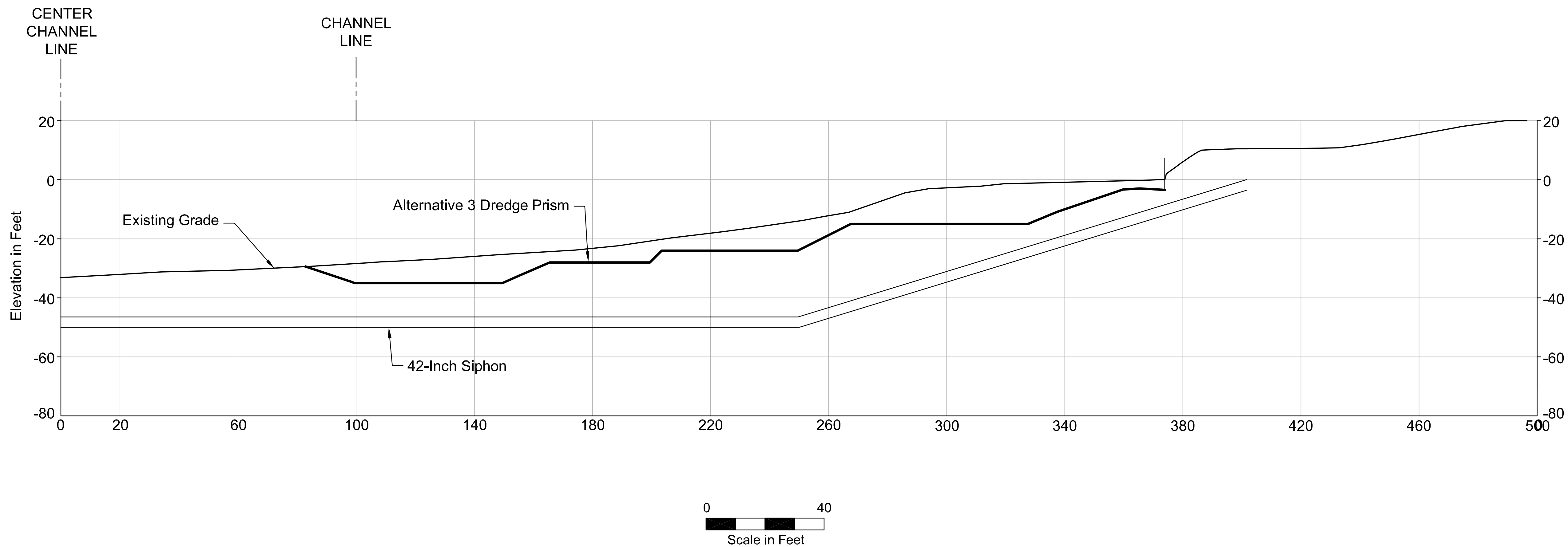
00-086-01
DWD006-01
12/19/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Alternative 4: Removal of all Contanimants, Dredge Layout (Plan View)

Figure 8-5



00-086-01

DWD007-01

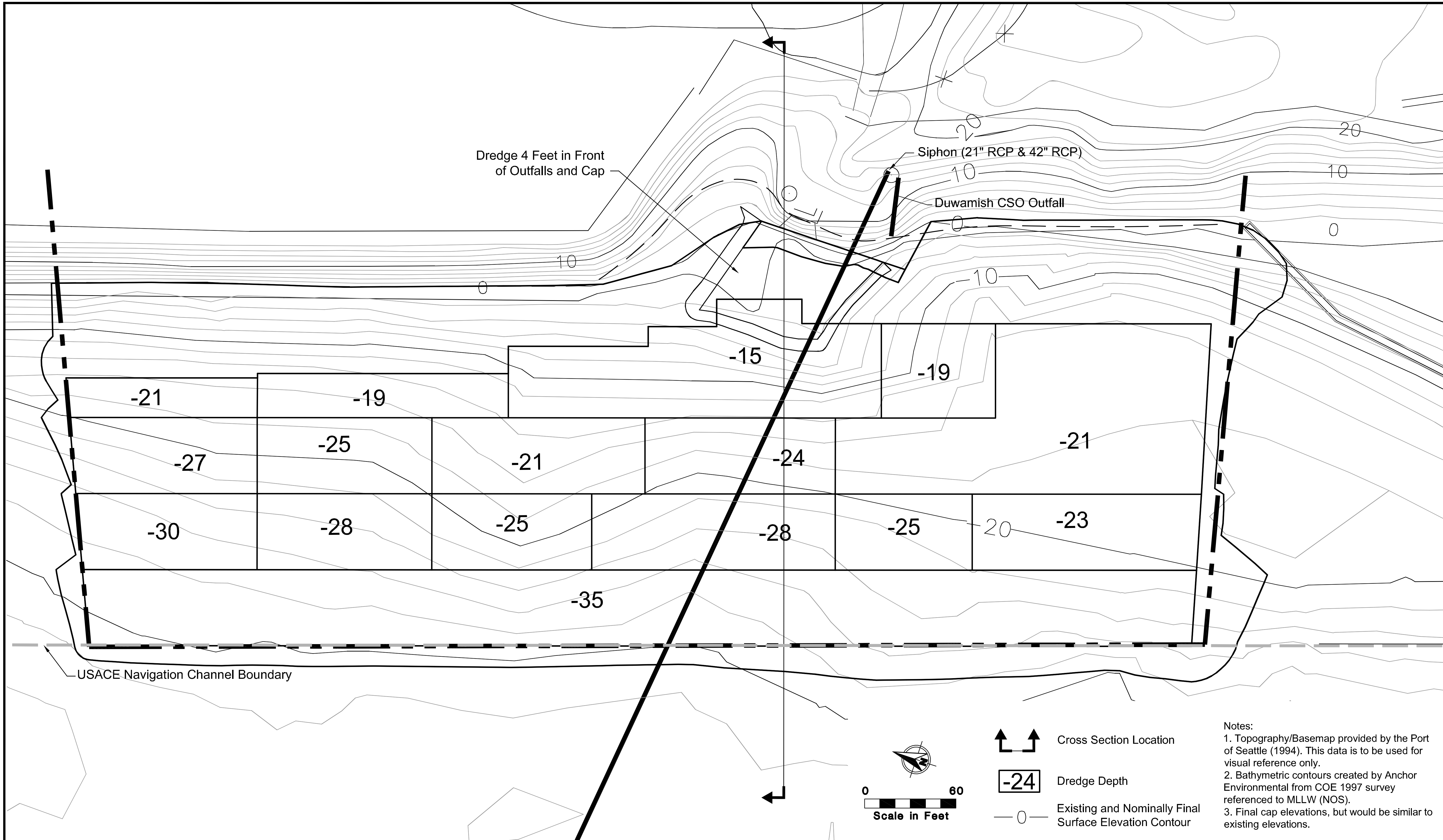
12/20/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Altternative 3: Cross Section

Figure 8-4



Cross Section Location

-24 Dredge Depth

0 Existing and Nominally Final Surface Elevation Contour

Notes:
1. Topography/Basemap provided by the Port of Seattle (1994). This data is to be used for visual reference only.
2. Bathymetric contours created by Anchor Environmental from COE 1997 survey referenced to MLLW (NOS).
3. Final cap elevations, but would be similar to existing elevations.

00-086-01

DWD006-01

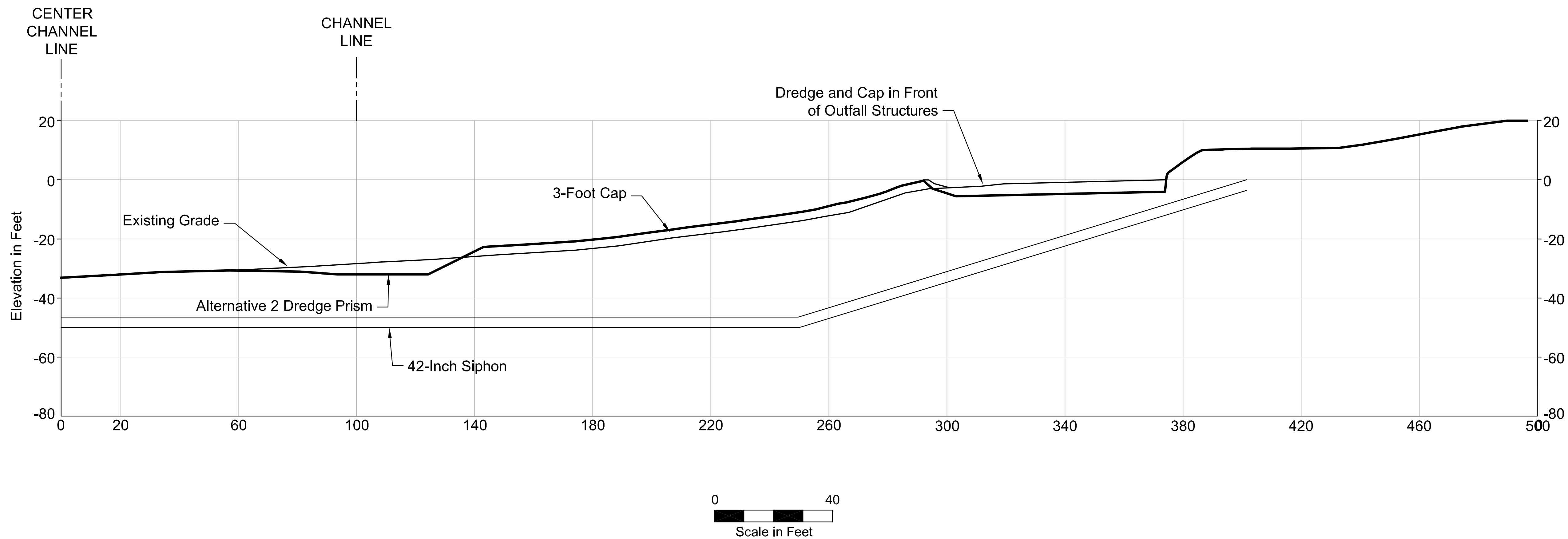
12/19/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Alternative 3: Capping with No Change in Existing Elevations, Dredge Layout (Plan View)

Figure 8-3



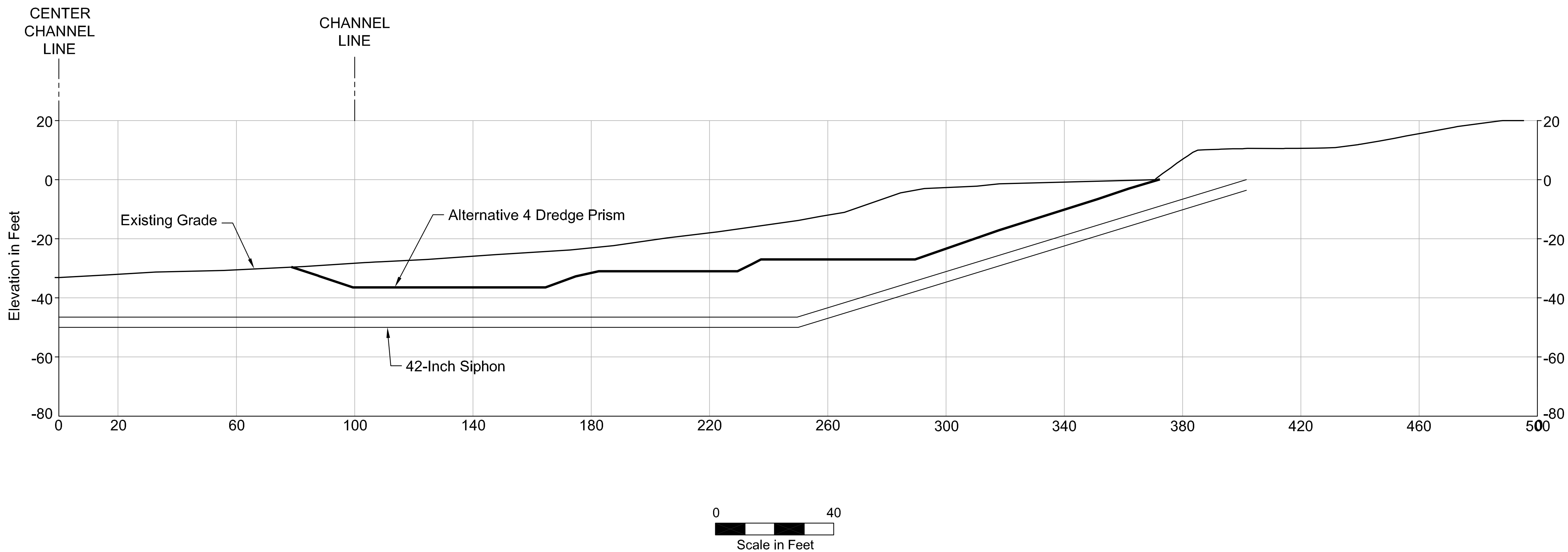
00-086-01
DWD007-01
12/20/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Altternative 2: Cross Section

Figure 8-2



00-086-01

DWD007-01

12/20/01

EcoChem Team

Duwamish/Diagonal Sediment Remediation Project

Altternative 4: Cross Section

Figure 8-6

9 DETAILED EVALUATION OF ALTERNATIVES

In Chapter 8, technology and process options were assembled into alternatives and were screened using the threshold criteria of technical effectiveness, implementability, cost effectiveness, and adverse impacts. In this chapter, the alternatives are evaluated in detail against eight criteria presented in WAC 173-204-560(4)(f)(iii). These criteria include:

1. Overall protection of human health and the environment, time required to attain the cleanup standard(s), and on-site and off-site environmental impacts and risks to human health resulting from implementing the cleanup alternatives.
2. Compliance with cleanup standards and applicable federal, state, and local laws.
3. Short-term effectiveness, including protection of human health and the environment during construction and implementation of the alternative.
4. Long-term effectiveness, including degree of certainty that the alternative will be successful, long-term reliability, magnitude of residual biological and human health risk, effectiveness of controls for ongoing discharges, management of treatment residues, and disposal site risks.
5. The ability to be implemented including the potential for landowner cooperation, technical feasibility, availability of needed off-site facilities, services, and materials, administrative and regulatory requirements, scheduling, monitoring requirements, access for construction, operations and monitoring, and integration with existing operations and other current or potential cleanup actions.
6. Cost, including consideration of present and future direct and indirect capital, operation, and maintenance costs and other foreseeable costs.
7. The degree to which community concerns are addressed.
8. The degree to which recycling, reuse, and waste minimization are employed.

This chapter concludes with a comparison of the alternatives and the selection of the preferred alternative.

9.1 ALTERNATIVE 1: NO ACTION

The No Action alternative is included as a baseline alternative to which other alternatives can be compared. Under this alternative no remedial action or institutional controls would be implemented and nothing would be done to mitigate existing impacts to human health and the environment. Improvement in the level of contamination at the site resulting from degradation of contaminants by natural chemical, physical, and biological processes is unlikely.

9.1.1 Overall Protection of Human Health and the Environment

This alternative would not provide protection of human health and the environment; no remedial action would be performed.

9.1.2 Compliance with Cleanup Standards and Applicable Laws

This alternative does not comply with cleanup standards or applicable laws since phthalate, PCB, and mercury contamination would remain exposed on site at concentrations above the MCUL

9.1.3 Short-Term Effectiveness

This alternative is not effective in the short term, but would also not result in any short-term increases in contaminant releases beyond existing conditions.

9.1.4 Long-Term Effectiveness

The long-term risk remains unchanged under this alternative.

9.1.5 Implementability

There are no actions to implement under this alternative.

9.1.6 Cost

There is no cost associated with this alternative.

9.1.7 Community Concerns

There would not be a public comment period, as there would be no action to trigger such comment. However, it is assumed that this alternative may not be acceptable to the public.

9.1.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

9.2 ALTERNATIVE 2: MAXIMUM PRACTICABLE CONTAINMENT

This alternative would place a thick cap (3 feet) of clean sand or other appropriate grain size to avoid erosion over the site to contain the contaminated sediments. This would isolate contamination from the environment and would generally raise the elevation of the site by three feet, thereby increasing the area of shallow subtidal and low intertidal habitat zones. The area immediately adjacent to the navigation channel would have to be dredged to minimize encumbrances on future maintenance needs. The area in front of the outfall would also have to be dredged, so the cap would not impede discharge flows.

9.2.1 Overall Protection of Human Health and the Environment

This alternative will provide protection of human health and the environment by isolating contaminated materials. Engineering controls would be instituted during dredging, dewatering, and capping operations to ensure that dredged material and water are properly contained and disposed of and the potential for resuspension of contaminants is minimized during dredging and capping operations. Any dredged sediment would be disposed of in an approved disposal facility. Cleanup standards would be met once the cap is entirely in place. Placing a thick cap would likely smother the existing benthic community. Similarly, dredging of contaminated sediments will temporarily disrupt and/or destroy the existing benthic community. Recolonization would be expected to occur within a year of the remedial action. Placing a thick cap over the existing sediments will increase the elevation of those sediments. Approximately two-thirds of the site is located below -13 feet MLLW; therefore, placing a 3-foot thick cap over the site may not materially affect the habitat type in this portion of the site. However, areas located above -13 feet MLLW may change from deep subtidal zone to shallow subtidal zone, shallow subtidal zone to low intertidal zone, or low intertidal zone to high intertidal zone. Generally, the low intertidal zone (-4 to +4 feet MLLW) is considered to have a greater habitat value for salmonids. This thick layer cap would increase the amount of low intertidal habitat by approximately 0.19 acres.

9.2.2 Compliance with Cleanup Standards and Applicable Laws

This alternative would comply with cleanup standards and all applicable laws. All required permits would be obtained prior to performing the remedial activities. Water quality permits would be obtained and implemented to ensure that water quality is not degraded during dredging and capping. The dredged materials would be placed in a fully permitted disposal facility.

9.2.3 Short-Term Effectiveness

Dredging and capping could create limited adverse water quality impacts at the site resulting from sediment suspension in the water column. Resuspension could cause turbidity and migration of sediments. If turbidity is anticipated to reach levels of concern, silt curtains could be used to limit migration. Work would not be performed during the time that juvenile salmonids migrate through the area. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

9.2.4 Long-Term Effectiveness

This alternative is effective because it isolates all contaminated materials either in approved disposal facilities or under a thick cap.

To ensure the long-term effectiveness of this alternative the area immediately adjacent to the navigation channel would have to be dredged so that future maintenance actions undertaken within the navigation channel would not affect the integrity of the cap.

Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these would include anchoring, dragging, digging, and pile driving without proper conditions.

A sediment impact zone authorized by Ecology and in compliance with WAC 173-204-590 may be required in the vicinity of the Duwamish/Diagonal outfalls if phthalate releases from the existing stormwater outfalls are not sufficiently controlled. The need for a sediment impact zone for this project has been discussed with Ecology and the Sediment Management Group will take an active role in this process. The size and duration of the recovery zone would be determined during the design phase of the project using the methods described in WAC 173-204-590. Phthalate releases would likely be addressed in the future through the conditions of Ecology's authorization.

The PCB modeling performed in **Section 7.4** predicts that the final surface would temporarily recontaminate to levels greater than the SQS but significantly below the MCUL due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

9.2.5 Implementability

This alternative is technically implementable. Dredging and capping are reliable, proven technologies. No difficulty in obtaining right-of-entry and access agreements for construction is anticipated. The equipment is available locally. However, there are three possible difficulties with implementation of this alternative. First it has the potential to impact Tribal Treaty fishing by altering the bathymetry. Second, the Port of Seattle owns the adjacent properties and would likely resist any alternative that would limit their current uses of the site, including the reduced water depths in the vicinity of the E-pier. Finally, NMFS and USFWS may resist the filling of the site due to a net loss of shallow subtidal habitat.

The off loading and rehandling site at the former Crowley dock at Harbor Island (which is owned by the Port of Seattle) is expected to be available for use. If for some reason it were not available, Rabanco has agreements with the Port to utilize other similar facilities. If dewatering were required prior to loading the sediments into the railcars, a dewatering facility would be constructed at the offloading site.

9.2.6 Cost

The estimated cost for this alternative is $2,450,000. The preliminary cost estimate is detailed in **Table 9.1**.

9.2.7 Community Concerns

It is not possible to evaluate the community's concerns regarding this alternative until after the public comment period. The public comment period will extend for a 30-day period during which the public will be asked to provide their evaluation, advice, and any concerns they have regarding all potential alternatives.

9.2.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

9.3 ALTERNATIVE 3: CAPPING WITH NO CHANGE IN EXISTING ELEVATIONS

This alternative includes dredging sufficient contaminated material to allow placement of a thick layer cap and retention of existing elevations. This would allow existing site uses to continue and future site uses to be performed under the current conditions. The existing habitat elevations would remain.

Table 9.1 COST ESTIMATE FOR ALTERNATIVE 2: MAXIMUM PRACTICABLE CONTAINMENT

Item	Quantity	Unit	Unit Cost	Cost	Notes
Preconstruction					
Mobilization/Demobilization	1	EA	$ 60,000	$ 60,000	1, 2
Pre- and Post-Dredge Survey	2	EA	$ 37,000	$ 74,000	
Dredge and Transport	9,500	CY	$ 10.00	$ 95,000	3, 4, 5, 6, 7
Rehandle to Rail Cars	10,450	CY	$ 2.00	$ 20,900	8, 9
Upland Disposal	15,675	Ton	$ 26.00	$ 407,550	10, 11
Thick Cap					
Purchase and Deliver	33,000	Ton	$ 8.25	$ 272,250	11, 12
Place	33,000	Ton	$ 6.25	$ 206,250	
Armor Shore Protection					
Purchase and Deliver	2,500	Ton	$ 13.00	$ 32,500	11, 13
Place	2,500	Ton	$ 8.50	$ 21,250	
Habitat Mitigation	1	LS	TBD	$ -	14
Subtotal				$ 1,189,700	
Tax		Percent	8.61%	$ 102,433	
Bond		Percent	1%	$ 11,897	
Contractor Profit		Percent	10%	$ 118,970	
Total Construction Cost				$ 1,423,000	
Engineering Design		Percent	8%	$ 113,840	
Construction Monitoring/Mgmt.		Percent	5%	$ 71,150	
Legal/ Administrative	3	FTE	$ 90,000	$ 243,000	
Permits, Fees, Misc. Expenses	1	EA	$ 25,000	$ 25,000	
Long Term Monitoring	1	LS	$ 165,000	$ 165,000	15
Total Project Cost				$ 2,040,990	
Contingency		Percent	20%	$ 408,198	
TOTAL (Rounded to $10,000)				**$ 2,450,000**	

Notes:

1 No demolition of structures required.
2 Coordination with the Port of Seattle not included.
3 No costs for land rental or lease for dewatering facility included.
4 Mechanical dredging with an 8 cy digging bucket.
5 Two 1,500 cy haul barges used.
6 One tug boat dedicated to project.
7 Minimal debris will be encountered.
8 Ten percent bulking factor included for rehandling.
9 Rail car will be adjacent to the wharf.
10 Disposal cost based on Quote from Rabanco, November 15, 2001. Includes off load from barge, placement into lined container, haul to landfill and tipping fee at landfill. Variation between
11 One cubic yard assumed to equal 1.5 tons (or one ton equals 0.67 cubic yard)
12 Prices for sand, gravel, and armor stone from LoneStar Industries. (Could be obtained for minimal cost from Turning Basin.)
13 Shore protection included for dressing up the bank, includes 2-foot thick layer.
14 Habitat Mitigation costs are To Be Determined (TBD)
15 Long -Term Monitoring based on $20,000/yr for 10 yrs; discount=7%, Inflation=3%

9.3.1 Overall Protection of Human Health and the Environment

This alternative will provide protection of human health and the environment by isolating contaminated materials. Engineering controls would be instituted during dredging and dewatering operations to ensure that dredged material and water are properly contained and disposed of and the potential for resuspension of contaminants is minimized during capping operations. Any dredged sediment would be disposed of in an approved disposal facility. Cleanup standards would be met once the cap is entirely in place. Dredging of contaminated sediments will temporarily destroy the existing benthic community. The site would be capped immediately after dredging operations, providing a clean surface for the benthic organisms. Recolonization would be expected to occur within a year of the remedial action. There would be no significant change in the areas of habitat zones under this alternative.

9.3.2 Compliance with Cleanup Standards and Applicable Laws

This alternative would comply with cleanup standards and all applicable laws. All required permits would be obtained prior to performing the remedial activities. Water quality permits would be obtained and control measures would be implemented to ensure that water quality is not degraded during dredging and capping. The dredged materials would be placed in a fully permitted disposal facility.

9.3.3 Short-Term Effectiveness

Dredging and capping could create limited adverse water quality impacts at the site resulting from sediment suspension in the water column. Resuspension could cause turbidity and migration of sediments. If turbidity is anticipated to reach levels of concern, silt curtains could be used to limit migration. In-water work would not be performed during the time that juvenile salmonids migrate through the area. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

9.3.4 Long-Term Effectiveness

This alternative is effective because it removes contaminants to an approved disposal facility and isolates remaining contaminated materials under a thick cap.

To ensure the long-term effectiveness of this alternative the area immediately adjacent to the navigation channel would to be dredged so that future maintenance actions undertaken within the navigation channel would not affect the integrity of the cap. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these would include anchoring, dragging, digging, and pile driving without proper conditions.

A sediment impact zone authorized by Ecology and in compliance with WAC 173-204-590 may be required in the vicinity of the Duwamish/Diagonal outfalls if phthalate releases from the existing stormwater outfalls are not sufficiently controlled. The need for a sediment impact zone for this project has been discussed with Ecology and the Sediment Management Group will take an active role in this process. The size and duration of the recovery zone would be determined during the design phase of the project using the methods described in WAC 173-204-590. Phthalate releases would likely be addressed in the future through the conditions of Ecology's authorization.

The PCB modeling performed in **Section 7.4** predicts that the final surface would temporarily recontaminate to levels greater than the SQS but significantly below the MCUL due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

9.3.5 Implementability

This alternative is technically implementable. Dredging and capping are reliable, proven technology. The equipment is available locally and the site is accessible. No difficulty in obtaining right-of-entry and access agreements is anticipated. **Sections 8.3** and **9.2.5** discuss the assumptions and use of upland rehandling facilities.

9.3.6 Cost

The estimated cost for this alternative is $5,890,000. The preliminary cost estimate is detailed in Table 9.2.

9.3.7 Community Concerns

It is not possible to evaluate the community's concerns regarding this alternative until after the public comment period. The public comment period will extend for a 30-day period during which the public will be asked to provide their evaluation, advice, and any concerns they have regarding all potential alternatives.

9.3.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

9.4 ALTERNATIVE 4: MAXIMUM PRACTICABLE REMOVAL OF CONTAMINANTS

This alternative includes removal, to the maximum extent practicable, of all contaminated sediments by dredging to historical dredge depths. The site would then be backfilled, as necessary, with clean sand to restore it to current elevations. This would allow for all existing site uses to continue and future site uses to be performed under the current conditions. The existing habitat elevations would remain.

9.4.1 Overall Protection of Human Health and the Environment

This alternative will provide protection of human health and the environment by removing, to the maximum extent practicable, all contaminated materials and isolating them in an approved disposal facility. Engineering controls would be instituted during dredging and dewatering operations to ensure that dredged material and water are properly contained and disposed.

Table 9.2 COST ESTIMATE FOR ALTERNATIVE 3: CAPPING WITH NO CHANGE IN EXISTING ELEVATIONS

Item	Quantity	Unit	Unit Cost	Cost	Notes
Preconstruction					
Mobilization/Demobilization	1	EA	$ 60,000	$ 60,000	1, 2
Pre- and Post-Dredge Surveys	2	EA	$ 37,000	$ 74,000	
Dredge and Transport	42,500	CY	$ 10.00	$ 425,000	3, 4, 5, 6, 7
Rehandle to Rail Cars	46,750	CY	$ 2.00	$ 93,500	8, 9
Upland Disposal	70,125	Ton	$ 24.00	$ 1,683,000	10, 11
Thick Cap					
Purchase and Deliver	63,750	Ton	$ 8.25	$ 525,938	11, 12
Place	63,750	Ton	$ 6.25	$ 398,438	
Armor Shore Protection					
Purchase and Deliver	2,500	Ton	$ 13.00	$ 32,500	11, 13
Place	2,500	Ton	$ 8.50	$ 21,250	
Habitat Mitigation	1	LS	TBD	$ -	14
Subtotal				$ 3,313,625	
Tax		Percent	8.61%	$ 285,303	
Bond		Percent	1%	$ 33,136	
Contractor Profit		Percent	10%	$ 331,363	
Total Construction Cost				$ 3,963,427	
Engineering Design		Percent	8%	$ 317,074	
Construction Monitoring/Mgmt.		Percent	5%	$ 198,171	
Legal/ Administrative	3	FTE	$ 90,000	$ 243,000	
Permits, Fees, Misc. Expenses	1	EA	$ 25,000	$ 25,000	
Long Term Monitoring	1	LS	$ 165,000	$ 165,000	15
Total Project Cost				$ 4,911,672	
Contingency		Percent	20%	$ 982,334	
TOTAL (Rounded to $10,000)				**$ 5,890,000**	

Notes:
1 No demolition of structures required.
2 Coordination with the Port of Seattle not included.
3 No costs for land rental or lease for dewatering facility included.
4 Mechanical dredging with a 12 cy digging bucket.
5 Two 1,500 cy haul barges used.
6 One tug boat dedicated to project.
7 Minimal debris will be encountered.
8 Ten percent bulking factor included for rehandling.
9 Rail car will be adjacent to the wharf.
10 Disposal cost based on Quote from Rabanco, November 15, 2001. Includes off load from barge, placement into lined container, haul to landfill and tipping fee at landfill. Variation between
11 One cubic yard assumed to equal 1.5 tons (or one ton equals 0.67 cubic yard)
12 Prices for sand, gravel, and armor stone from LoneStar Industries. (Could be obtained for minimal cost from Turning Basin.)
13 Shore protection included for dressing up the bank, includes 2-foot thick layer.
14 Habitat Mitigation costs are To Be Determined (TBD)
15 Long -Term Monitoring based on $20,000/yr for 10 yrs; discount=7%, Inflation=3%

9.4.2 Compliance with Cleanup Standards and Applicable Laws

This alternative would comply with cleanup standards and all applicable laws. All required permits would be obtained prior to performing the remedial activities. Water quality permits would be obtained and implemented to ensure that water quality is not degraded during dredging and capping. The dredged materials would be placed in a fully permitted disposal facility.

9.4.3 Short-Term Effectiveness

Dredging and capping could create limited adverse water quality impacts at the site resulting from sediment suspension in the water column. Resuspension could cause turbidity and migration of sediments. If turbidity is anticipated to reach levels of concern, silt curtains could be used to limit migration. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

9.4.4 Long-Term Effectiveness

This alternative is effective because it removes contaminants to an approved disposal facility and isolates remaining contaminated materials under a thick cap.

To ensure the long-term effectiveness of this alternative the area immediately adjacent to the navigation channel would be dredged so that future maintenance actions undertaken within the navigation channel would not affect the integrity of the cap. Institutional controls to prevent disturbance to the cap would be negotiated with the Port of Seattle and other landowners; these would include anchoring, dragging, digging, and pile driving without proper conditions.

A sediment impact zone authorized by Ecology and in compliance with WAC 173-204-590 may be required in the vicinity of the Duwamish/Diagonal outfalls if phthalate releases from the existing stormwater outfalls are not sufficiently controlled. The need for a sediment impact zone for this project has been discussed with Ecology and the Sediment Management Group will take an active role in this process. The size and duration of the recovery zone would be determined during the design phase of the project using the methods described in WAC 173-204-590. Phthalate releases would likely be addressed in the future through the conditions of Ecology's authorization.

The PCB modeling performed in **Section 7.4** predicts that the final surface would temporarily recontaminate to levels greater than the SQS but significantly below the MCUL due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

9.4.5 Implementability

This alternative is technically implementable. Dredging and capping are reliable, proven technologies. The equipment is available locally and the site is accessible. No difficulty in obtaining right-of-entry and access agreements is anticipated. **Sections 8.3** and **9.2.5** discuss the assumptions and use of upland rehandling facilities.

9.4.6 Cost

The estimated cost for this alternative is $10,610,000. The preliminary cost estimate is detailed in Table 9.3.

9.4.7 Community Concerns

It is not possible to evaluate the community's concerns regarding this alternative until after the public comment period. The public comment period will extend for a 30-day period during which the public will be asked to provide their evaluation, advice, and any concerns they have regarding all potential alternatives.

9.4.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with this alternative.

Table 9.3 COST ESTIMATE FOR ALTERNATIVE 4: MAXIMUM PRACTICABLE REMOVAL OF CONTAMINANTS

Item	Quantity	Unit	Unit Cost	Cost	Notes
Preconstruction					
Mobilization/Demobilization	1	EA	$ 60,000	$ 60,000	1, 2
Pre- and Post-Dredge Surveys	2	EA	$ 37,000	$ 74,000	
Dredge and Transport	82,000	CY	$ 10.00	$ 820,000	3, 4, 5, 6, 7
Rehandle to Rail Cars	90,200	CY	$ 2.00	$ 180,400	8, 9
Upland Disposal	135,300	Ton	$ 24.00	$ 3,247,200	10, 11
Thick Cap					
Purchase and Deliver	123,000	Ton	$ 8.25	$ 1,014,750	11, 12
Place	123,000	Ton	$ 6.25	$ 768,750	
Armor Shore Protection					
Purchase and Deliver	2,500	Ton	$ 13.00	$ 32,500	11, 13
Place	2,500	Ton	$ 8.50	$ 21,250	
Habitat Mitigation	1	LS	TBD	$ -	14
Subtotal				$ 6,218,850	
Tax		Percent	8.61%	$ 535,443	
Bond		Percent	1%	$ 62,189	
Contractor Profit		Percent	10%	$ 621,885	
Total Construction Cost				$ 7,438,366	
Engineering Design		Percent	8%	$ 595,069	
Construction Monitoring/Mgmt.		Percent	5%	$ 371,918	
Legal/ Administrative	3	FTE	$ 90,000	$ 243,000	
Permits, Fees, Misc. Expenses	1	EA	$ 25,000	$ 25,000	
Long Term Monitoring	1	LS	$ 165,000	$ 165,000	15
Total Project Cost				$ 8,838,354	
Contingency		Percent	20%	$ 1,767,671	
TOTAL (Rounded to $10,000)				**$ 10,610,000**	

Notes:
1 No demolition of structures required.
2 Coordination with the Port of Seattle not included.
3 No costs for land rental or lease for dewatering facility included.
4 Mechanical dredging with a 12 cy digging bucket.
5 Two 1,500 cy haul barges used.
6 One tug boat dedicated to project.
7 Minimal debris will be encountered.
8 Ten percent bulking factor included for rehandling.
9 Rail car will be adjacent to the wharf.
10 Disposal cost based on Quote from Rabanco, November 15, 2001. Includes off load from barge, placement into lined container, haul to landfill and tipping fee at landfill. Variation between
11 One cubic yard assumed to equal 1.5 tons (or one ton equals 0.67 cubic yard)
12 Prices for sand, gravel, and armor stone from LoneStar Industries. (Could be obtained for minimal cost from Turning Basin.)
13 Shore protection included for dressing up the bank, includes 2-foot thick layer.
14 Habitat Mitigation costs are To Be Determined (TBD)
15 Long -Term Monitoring based on $20,000/yr for 10 yrs; discount=7%, Inflation=3%

9.5 COMPARISON OF REMEDIAL ALTERNATIVES

The alternatives are compared below to evaluate their relative performance in relation to each of the eight cleanup study criteria. The purpose of this comparison is to identify advantages and disadvantages of each alternative relative to the others. This will facilitate the selection process by identifying key tradeoffs. For each criterion, the alternatives are qualitatively ranked in order of desirability. **Table 9.4** presents a summary of the alternatives comparison.

Table 9.4 ALTERNATIVES COMPARISON

Criterion	Alternative 1: No Action	Alternative 2: Maximum Practicable Containment	Alternative 3: Capping with No Change in Existing Elevations	Alternative 4: Maximum Practicable Removal of Contaminants
Overall Protection of Human Health and the Environment	Continued environmental exposure. Potential for human exposure to contaminated sediments. Uptake of contaminants by organisms and subsequent ingestion is primarily human exposure pathway.	Isolation and removal of contaminated sediments would eliminate exposure pathways from site.	Removal and isolation of contaminated sediments would eliminate exposure pathways from site. Maintaining existing elevations improves cap stability.	Same as Alternative 3.
Compliance with Cleanup Standards and Applicable Laws	Does not comply.	Isolation and removal of contaminated sediments will comply with cleanup standards. All required permits would be obtained and complied with.	Same as Alternative 2.•	Same as Alternative 2.
Short-Term Effectiveness	Not applicable.	Low risk to the public at dredge and handling sites. Workers required to use proper health and safety procedures. Potential water quality issues, which can be addressed.	Similar to Alternative 2, though more material is handled.	Similar to Alternatives 2 and 3, though more material is handled.
Long-Term Effectiveness	Not effective.	Effective as all contaminated sediments are removed or isolated under an engineered cap.	Similar to Alternative 2, though more material is removed.	Similar to Alternatives 2 and 3, though more material is removed.

Implementability	No action to implement. Violates CD	Readily implemented provided navigational and fishing issues worked out.	Readily implemented.	Same as Alternative 3.
Cost	No cost.	$2.45 million	$5.89 million	$10.6 million
Community Concerns	Assumed to be unacceptable.	Not possible to evaluate until after public comment period.	Same as Alternative 2.	Same as Alternative 2.
Employment of Recycling, Reuse, and Waste Minimization	None.	None.	None.	None.

9.5.1 Overall Protection of Human Health and the Environment

Alternative 1 would not provide any additional protection of human health and the environment. Alternatives 2, 3, and 4 isolate some or most the contaminants with a thick layer cap, with increasing volumes of removal, respectively. The cap will be designed to be stable for the currents and wave conditions expected at the site. Alternative 2 would reduce the existing water depths by approximately three feet, which could increase the velocities in the area of the cap, however this is not anticipated to be significant, as a 3-foot increase over this portion of the river would decrease the cross-section of the river by approximately two percent. Alternative 3 removes approximately 42,500 cy (63,750 tons) of sediment, which would no longer be available for potential release if the cap failed. Alternative 4 removes approximately 82,000 cy (123,000 tons) of sediment, which is all sediment that can be removed without risking potential damage to the siphons.

Overall Protection Ranking: Alternative 4=Alternative 3>Alternative 2>Alternative 1.

9.5.2 Compliance with Cleanup Standards and Applicable Laws

Alternative 1 would not comply with cleanup standards or applicable laws. Alternatives 2, 3, and 4 would isolate or remove all sediments with contaminant concentrations greater than the cleanup standards. Under Alternatives 2, 3, and 4, all applicable permits would be obtained and complied with. It may be easier to obtain permits for Alternatives 3 and 4 due to concerns over nearshore fill, habitat alteration, and Tribal fishing rights in Alternative 2. Maintenance access for the navigational channel would be maintained under all of the alternatives. Dredged sediments would be placed in a fully permitted facility.

Overall Compliance Ranking: Alternative 4=Alternative 3>Alternative 2>Alternative 1.

9.5.3 Short-Term Effectiveness

This criterion is not applicable to Alternative 1. Alternatives 2, 3, and 4 employ dredging and capping which could create limited adverse water quality impacts at the dredging site. If resuspension is anticipated to occur at levels of concern, silt curtains could be use to limit migration of suspended sediments. However, silt curtains are not wholly effective in tidal environments. Moreover, the greater the amount of dredging the greater the potential risk for releases during dredging operations. Engineering controls would be required to prevent or contain spillage during transfer operations from the haul barge to the upland rehandling site.

Overall Ranking: Alternative 2>Alternative 3>Alternative 4.

9.5.4 Long-Term Effectiveness

Alternative 1 is not effective in the long-term. Alternatives 2, 3, and 4 are effective because they remove contaminants to an approved disposal facility and isolate remaining contaminated materials under a thick cap. Because Alternative 4 removes more material than Alternative 3 (which removes more than Alternative 2) and places it in an engineered, fully monitored landfill, it is preferred.

All caps placed at the site will be designed to comply with EPA and USACE guidance so that they will be stable. As mentioned above, Alternatives 2's 3-foot cap will extend above the channel bed will decrease the cross-sectional area of the river by approximately 2 percent. The resultant increase in water velocities is not anticipated to cause the cap to be scoured away (as it would be designed to withstand this), though there would be an increased risk of failure.

To ensure the long-term effectiveness of capping immediately adjacent to the navigation channel, a strip would be dredged to -35 feet MLLW and capped to -32 feet MLLW. This will allow future maintenance actions undertaken within the navigation channel (authorized to a depth of -30 feet MLLW) to not affect the integrity of the cap.

A sediment impact zone authorized by Ecology and in compliance with WAC 173-204-590 may be required for Alternatives 2, 3, and 4 in the vicinity of the Duwamish/ Diagonal outfalls, if phthalate releases from the existing stormwater outfalls are not sufficiently controlled. These releases would likely be addressed in the future under the conditions of Ecology's authorization.

The PCB modeling performed in **Section 7.3** and **Appendix P** predicts that the final capped surface of Alternatives 2, 3, and 4 may temporarily recontaminate to levels greater than the SQS but significantly below the MCUL due to the general flux of PCB within the waterway. As additional cleanup projects are performed under the MTCA and CERCLA programs, this background level will be reduced and it is anticipated that PCB concentrations will eventually be reduced to levels below the SQS.

Overall Ranking: Alternative 4>Alternative 3>Alternative 2>Alternative 1.

9.5.5 Implementability

Alternative 1 No Action, is easily implemented, since there is no action to perform; however, this alternative would not be administratively implementable as it would violate the Consent Decree (**Section 6.1.1.2**).

Alternatives 2, 3, and 4 are technically implementable. Dredging and capping equipment and experience personnel are available locally. The technology is reliable and proven. The actions taken in Alternatives 2, 3, and 4 are very similar, but the quantities involved differ. It may be easier to obtain permits for Alternatives 3 and 4 due to concerns over nearshore fill, habitat alteration, and Tribal fishing rights in Alternative 2.

Overall Implementability Ranking: Alternative 3=Alternative 4>Alternative 2> Alternative 1.

9.5.6 Cost

The estimated total costs for each alternative are summarized below:

Alternative 1: $0.
Alternative 2: $2,450,000.
Alternative 3: $5,890,000.
Alternative 4: $10,610,000.

The cost estimates provided in Tables 9.1 through 9.3 are feasibility study level estimates with an accuracy of -30 percent to +50 percent.

Overall Cost Ranking: Alternative 1>Alternative 2>Alternative 3>Alternative 4.

9.5.7 Community Concerns

It is not possible to compare this criterion for the various alternatives until after the public comment period. It is assumed at this point that action alternatives are preferred over the no action alternative.

9.5.8 Employment of Recycling, Reuse, and Waste Minimization

There are no recycling, reuse, or waste minimization procedures associated with any of the alternatives. The alternatives are equally ranked for this criterion.

9.6 PREFERRED ALTERNATIVE

The preferred alternative is Alternative 3: Capping with No Change in Existing Elevation. For ease of reference this alternative is described again here and a justification for the choice follows the description.

The overall objective of Alternative 3 is to achieve SQS chemical criteria throughout the 4.8-acre cleanup site by removing a layer of the contaminated sediment and installing an isolating cap of clean sediment that maintains existing water depths and river bottom elevations throughout the site. To the extent practicable, this alternative minimizes dredging depths; however, additional dredging is included along the east channel line to remove possible future encumbrances to navigation deepening of the federal waterway and adjacent berthing areas.

The preferred alternative will achieve this objective by using a combination of proven and accepted remedial technologies. The surface layer throughout the site would be removed by mechanical dredging to accommodate cap backfill and all dredge materials would be disposed off-site. The cap would be designed and constructed in accordance with EPA and USACE standards, in order to ensure its long term integrity and performance. Upland source controls such as pipe cleaning would be completed as a separate action prior to initiation of this remedial action. A sediment impact zone authorized by Ecology and in compliance with WAC 173-204-590 may be required in the vicinity of the Duwamish/Diagonal outfalls if phthalate input from the Diagonal storm water outfall cannot be totally controlled.

Under this preferred alternative, an average of approximately 5 feet (minimum 3 feet) of contaminated sediment (42,500 cy) would be removed from the Duwamish/Diagonal site using a mechanical clamshell dredge. Additional dredging depth is included in a 50-foot wide stripe along the east channel line to ensure that after the cap is placed, the cap surface will be two feet below the USACE's 30-foot channel depth. Along the inshore boundary, the dredge cuts are set back so the existing rip-rap shoreline will not collapse. A slope of 3H:1V has been used for external side slopes and 2H:1V for internal slopes, due to the depth of the cuts (**Figure 8-4**). Dredged sediment will be loaded onto a haul barge for transport to an off-site disposal facility. The four potential off-site disposal facilities are either an upland landfill (as assumed in the cost estimates), a confined aquatic disposal site (CAD), a near shore confined disposal (NCD), or a sediment multi-user remediation facility (SMURF). The EBDRP Panel will select from among these four prospective disposal/treatment options during remedial design, based on consideration of availability, cost, and other relevant factors. If sediment must be shipped to a disposal facility, an approved transfer operation will be used to off load and ship dredged sediment.

Following dredging, the remediation site will be capped with clean backfill material (42,500 cy) to isolate remaining sediment contamination from the environment. The exact thickness of the cap will be determined during design utilizing USACE and EPA guidance documents for designing isolation caps. For the purposes of this report it is assumed that the cap will be a minimum of 3 feet thick, but in many areas of the site the cap thickness will need to exceed 3 feet in order to return the site to existing elevations. Cap material would be chosen for stability and to the extent possible for habitat considerations. Although existing sediments are sandy-silt to silty-sands, the capping material selected for this project will probably contain coarser sediment materials to protect against erosion. Medium to coarse grained sand could be used to cap most of the site since this material has been successfully used in several other local capping projects. For the existing intertidal slope, the cap material would probably consist of a select mix of sand and gravel. Cobble size material would only be used if the design phase determined it was necessary to insure stability of the cap and slope in certain areas. The existing rip-rapped bank would be given a dressing layer of armor stone and fish mix (approximately 1,700 cy [2,500 tons]) to ensure the long-term stability of the slope and create a more fish-friendly slope.

No in-water work would be performed during the time that juvenile salmonids migrate through the area. Institutional controls to ensure the ongoing integrity of the cap would be negotiated with the Port of Seattle and other landowners. These include no anchoring, dragging, digging, or pile driving without proper conditions.

The following section summarizes the justification for selecting this alternative.

9.6.1 Justification of Preferred Alternative

Under CERCLA, MTCA, and SMS cleanup programs, potential remedial actions must be evaluated relative to a wide range of technical criteria, as presented above in **Section 9.0**. The selected remedy must meet certain threshold requirements, including protection of human health and the environment; compliance with cleanup standards; compliance with applicable state and federal laws; and provision for compliance monitoring. The preferred alternative meets these threshold criteria.

Compliance monitoring would be performed following the completion of the remedial action to ensure the continued effectiveness of the cleanup remedy. Though some recontamination is expected following construction of the cleanup action (**Section 7.3**), sediment PCB concentrations are not expected to exceed minor effects criteria (e.g., MCUL). However, as other locations within the Duwamish River are remediated it is expected that PCB levels will be further reduced (**Figures 7-5** and **7-6**) and concentrations will approach no effects criteria (e.g., SQS). Considering potential time frames of two to five years for remediation of surrounding sediment cleanup site, the time frame for restoration of the Duwamish/Diagonal site is expected to be within 10 years.

The selected remedy approved under CERCLA, MTCA, and SMS programs must also meet other balancing and modifying criteria, including the requirement that the remedy use permanent solutions to the maximum extent practicable. Permanent solutions are defined in the regulations as those remedial actions that meet cleanup standards with a minimum of further action being required either at the site or at the disposal/treatment facility. The MTCA Cleanup Standard Regulation sets forth a process to identify the most permanent remedy from among a range of possible cleanup alternatives (WAC 173-340-360(3)). If all other factors were equal, the remedial alternative that utilizes the greatest degree of on-site or off-site disposal in an engineered, lined, and monitored facility would be ranked more permanent than alternatives with a greater reliance on on-site isolation or containment with attendant engineering controls. If this were the case (i.e., if no other evaluation criterion were to be applied), Alternative 4: Maximum Practicable Removal of Contaminants would be the most permanent cleanup remedy.

However, MTCA, CERCLA, and SMS regulations also recognize that there may be other important factors, including cost, that need to be considered when determining whether a cleanup action uses permanent solutions to the maximum extent practicable. For example, the MTCA regulation sets forth a general test to determine whether the costs to implement a given cleanup remedy are disproportionate to the benefits achieved by that action. At the Duwamish/Diagonal site, Alternative 2 would be less costly than Alternative 3, which in turn would be less costly than Alternative 4. However, in determining whether the alternative uses permanent solutions to the maximum extent practicable, other balancing and modifying criteria are considered, including:

- Protectiveness (Alternatives 2 is ranked less protective than 3 and 4, which are equivalent; see **Table 9.4**);
- Employment of Recycling, Reuse, and Waste Minimization (Alternatives 2, 3, and 4 are equivalent; see **Table 9.4**);
- Effectiveness Over the Long Term (because it utilizes the greatest degree of disposal in an engineered, lined, and monitored facility, Alternative 4 is ranked higher than Alternative 3, which is turn is ranked higher than Alternative 2; see **Table 9.4**);
- Management of Short-Term Risks (Alternative 2 is ranked higher than Alternative 3, which in turn is ranked higher than Alternative 4; see **Table 9.4**);
- Technical and Administrative Implementability (Alternatives 3 and 4 are ranked higher than Alternative 2; see **Table 9.4**; also see below); and
- Consideration of public concerns (the public will comment on this draft Cleanup Study prior to formal selection of the cleanup action).

Based on the preliminary rankings summarized above (i.e., prior to considering public input), Alternative 3: Capping with No Change in Existing Elevation provides the same overall benefits as Alternative 4, but at a significantly lower cost. Both Alternatives 3 and 4 provide greater benefits than Alternative 2. Thus, consistent with the MTCA/SMS evaluation procedure (WAC 173-340-360(3)), Alternative 3 has been preliminarily identified as the option that uses permanent solutions to the maximum extent practicable. This potential selection will be reevaluated following public comment.

It is also important to note that the Panel currently has only a limited amount of funds available (approximately $8 million) in its Registry Account that can be utilized to implement the Duwamish/Diagonal cleanup action. The estimates presented in **Tables 9.2** and **9.3** indicate that Alternative 3 could be implemented at a total cost of less than $8 million, while the cost to implement Alternative 4 would substantially exceed the Panel's budget. Therefore, without supplemental funding from another entity(ies), Alternative 4 would be considerably more difficult to implement (administratively) than Alternative 3. These budgetary/implementability considerations provide further support for selection of Alternative 3 as the preferred cleanup remedy at the Duwamish/Diagonal Site.

As discussed above, this draft Cleanup Study will be provided to the public for review. In addition, Ecology will issue a Cleanup Action Decision document for this site that determines whether Ecology agrees that the proposed project meets the requirements of the Sediment Management Standards and other state laws. Both the Cleanup Action Decision document and the SEPA checklist will be made available for public comment along with the Cleanup Study. Public comments received could modify the cleanup analysis and/or preferred alternative presented herein. Changes will be documented in the final version of the Cleanup Study and the other documents. Implementation of the selected cleanup remedy, beginning with detailed remedial design and permitting, would commence in early 2002. Construction actions are currently targeted to occur in late 2003.

10 REFERENCES

Anchor and Foster Wheeler. 2001. Revised Final Data Evaluation Report. Prepared by Anchor Environmental, Seattle, Washington, and Foster Wheeler Environmental Corporation, Bothell, Washington, for Middle Waterway Action Committee, Tacoma, Washington. November 24, 2000, Revised April 9, 2001.

Applied Geotechnology, Inc. (AGI). 1992. Site Assessment Summary. Prepared for Chevron U.S.A. Products Company, Site Assessment and Remediation Group, Seattle. Bellevue, Washington: Applied Geotechnology, Inc.

ARM. 1991. Minutes of the Third Annual Puget Sound Dredge Disposal Program Annual Review Meeting (ARM). U.S. Army Corps of Engineers. Appendix D. May 2, 1991.

Boudreau, B. 1997. Diagenetic Models and Their Implementation, Springer-Verlag, Berlin, Germany.

Brown and Caldwell. 1958. Metropolitan Seattle Sewerage and Drainage Survey. Prepared for the City of Seattle, King County, and the State of Washington. Seattle, Washington: Brown and Caldwell.

Canning, D. J., S. G. Herman, and G. B. Shea. 1979. Terminal 107 Environmental Studies, Wildlife Study. Prepared for the Port of Seattle by the Oceanographic Institute of Washington and Northwest Environmental Consultants. Seattle, Washington.

Chapman, Peter M., J. Downie, A. Maynard, and L. A. Taylor. 1996. Coal and Deodorizer Residues in Marine Sediments-Contaminants or Pollutants? Environmental Toxicology and Chemistry, Vol. 15, No. 5, pp. 638-642.

City of Seattle. 1996. Unpublished Data. Seattle Engineering Department, Drainage and Wastewater Utility. Seattle, Washington.

Dail, Holly J. 1996. Likelihood of Sediment Erosion at the Diagonal Way Cleanup Site: Implications for Future Sediment Remediation. Senior Research Project Report, School of Oceanography, University of Washington.

Dexter, R., D. Anderson, E. Quinlan, L. Goldstein, R. Strickland, S. Pavlou, J. Clayton, R. Kocan, and M. Landolt. 1981. A Summary of Knowledge of Puget Sound Related to Chemical Contaminants (Technical Memorandum OMPA-13). Prepared by the National Oceanic and Atmospheric Administration. Boulder, Colorado.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1994a. Concept Document, Panel Publication 7. Prepared for the Elliott Bay/ Duwamish Restoration Program Panel by the King County Department of Metropolitan Services. Seattle, Washington. June 1994.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1994b. Duwamish/Diagonal Cleanup Study Workplan. Prepared for the Elliott Bay/Duwamish Restoration Program Panel by the King County Department of Metropolitan Services. Seattle, Washington August 1994.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1994c. Duwamish/Diagonal Sampling and Analysis Plan. Prepared for the Elliott Bay/Duwamish Restoration Program Panel by the King County Department of Metropolitan Services. Seattle, Washington. September 1994.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1994d. Duwamish/Diagonal and Norfolk Health and Safety Plan. Prepared for the Elliott Bay/Duwamish Restoration Program Panel by the King County Department of Metropolitan Services.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1994e. Duwamish/Diagonal and Norfolk Public Participation Plan. Prepared for the Elliott Bay/Duwamish Restoration Program Panel by the King County Department of Metropolitan Services.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1995. Elliott Bay Waterfront Recontamination Study, Vol. II. Data Evaluation and Remedial Design Recommendation Report. Prepared for EBDRP by the Aura Nova Consultant Contractor Team and Washington State Department of Ecology. Panel Publication. 10 August 1995.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1996a. Duwamish/Diagonal Phase II Sampling Analysis Plan. Prepared for the Elliott Bay/Duwamish Restoration Program Panel by the King County Department of Metropolitan Services. Seattle, Washington. April 1996.

Elliott Bay/Duwamish Restoration Program (EBDRP). 1996b. Norfolk Recontamination Modeling Report. Prepared for the Elliott Bay/Duwamish Restoration Program Panel by Kevin Schock and Randy Shuman, King County WPCD. Seattle, Washington. April 1996.

Environmental Solutions Group (ESG). 1999. Assessing Human Health Risks From the Consumption of Seafood: Human Health Risk Assessment Report. Waterway Sediment Operable Unit, Harbor Island Superfund Site. Prepared for the Port of Seattle, Lockheed Martin Corporation and Todd Shipyards. Prepared by Environmental Solutions Group, Seattle, Washington. September 1999.

EVS Consultants, Inc. and Hart Crowser. 1995. Supplementary Remedial Investigation Chemical Data Summary Report, Harbor Island Sediment Operable Unit, prepared for the Harbor Island Sediment Work Group c/o Port of Seattle, July 1995.

EVS Consultants, Inc. 1996. Harbor Island Sediment Operable Unit Supplemental Remedial Investigation Draft Report, Prepared by EVS Environmental Consultants for Harbor Island Sediment Work Group, April 1996.

Fischer, J.B., E.J. List, R.C.Y. Koh, J. Imberger, and N.H. Brooks, 1979. Mixing in Inland and Coastal Waters, Academic Press, Inc., Orlando, Florida.

GeoSea Consulting, Ltd. 1994. Sediment Transport in Elliott Bay and the Duwamish River, Seattle: Implications To Estuarine Management. Prepared for Washington Department of Ecology, Toxics Cleanup Program.

Grette, G. B. and E. O. Salo. 1986. The Status of Anadromous Fishes of the Green/Duwamish River System. Prepared for the U.S. Army Corps of Engineers, Seattle, Washington. Evans-Hamilton Inc., Seattle, Washington. June 1986.

Harper-Owes Company. 1983. Water Quality Assessment of the Duwamish Estuary, Washington. prepared for the Municipality of Metropolitan Seattle, Seattle, Washington. MET0026F. May 1983.

Hart Crowser, 2001. Final Report Contaminated Sediment Treatment Alternatives Analysis, Prepared for Washington State Department of Natural Resources, June 29, 2001, Work Order Number 0490-01-01-03-101034

Herrera Environmental Consultants, Inc. January 1995. Pollutant Loading Analyses, Elliott Bay Waterfront Recontamination Study. Prepared for Converse Consultants, Seattle, Washington and Washington State Department of Ecology. Seattle, Washington.

Hindmarsh, A.C. 1983. "ODEPACK, a systemized collection of ODE solvers," Scientific Computing, R. S. Stepleman et al., eds., North-Holland, Amsterdam, pp. 55-64.

Holtz, Robert D. and William D. Kovacs, 1981. An Introduction to Geotechnical Engineering, Prentice Hall Civil Engineering and Engineering Mechanics Series.

Howard, P. H. 1989. Handbook of Environmental Fate and Exposure Data for Organic Chemicals. Volume I Large Production and Priority Pollutants, Lewis Publishers.

Hylebos Cleanup Committee. 1999. Hylebos Waterway Pre-Remedial Design Evaluation Report, Commencement Bay Nearshore/Tideflats Superfund Site.

King County Department of Metropolitan Services (KCDMS). 1995. Combined Sewer Overflow Plan, 1995 Update. Prepared by Brown and Caldwell/KCM and Associated Firms for the King County Department of Metropolitan Services, Water Pollution Control Department, Seattle, Washington. February 1995.

King County Department of Natural Resources (KCDNR). 1999. King County combined sewer overflow water quality assessment for the Duwamish River and Elliott Bay. Prepared by King County Department of Natural Resources Wastewater Treatment Division and Water and Land Resources Division, Seattle, WA and Parametrix, Inc. Kirkland, WA.

King County Department of Natural Resources (KCDNR). 2000. Combined Sewer Overflow Plan, Year 2000 Update. Prepared by the King County Department of Natural Resources, Wastewater Treatment Division, and Brown & Caldwell, Inc., Seattle, Washington, June, 2000.

King County Environmental Laboratory (KCEL). 1995. Quality Assurance Review for Duwamish/Diagonal CSO Pre-Phase II Marine Sediment Sampling. Prepared for the Elliot Bay Duwamish Restoration Program. December 28, 1995;

King County Environmental Laboratory (KCEL). 1996a. Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study Phase II Marine Sediment Core Sampling. Prepared for the Elliot Bay Duwamish Restoration Program. August 21, 1996;

King County Environmental Laboratory (KCEL). 1996b. Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study Phase II Marine Sediment Grab Sampling and Study Phase II Marine Sediment Core Sampling. Prepared for the Elliot Bay Duwamish Restoration Program. November 12, 1996;

King County Environmental Laboratory (KCEL). 1997. Quality Assurance Review for Duwamish/Diagonal CSO Outfall Sediment Cleanup Study Phase II Archived Sediment Core Samples. Prepared for the Elliot Bay Duwamish Restoration Program. February 7, 1997.

Kissinger, Lon. 1999. Draft Approaches for Establishing Sediment Cleanup Levels for PCBs in Puget Sound Urban Bay Sediments. Prepared by Lon Kissinger, Washington State Department of Ecology. Downloaded from http://www.wa.gov/ecology/sea/smu/ic/ revision-sms.htm on June 16, 2000.

Lambe, T. William, and Robert V. Whitman. 1969. Soil Mechanics, John Wiley & Sons.

Mearns, A. J., M. Matta, G. Shigenaka, D. MacDonald, M. Buchman, H. Harris, J. Golas, and G. Lauenstein. 1991. Contaminant Trends in the Southern California Bight: Inventory and Assessment (Technical Memorandum NOS ORCA 62). Prepared by the National Ocean Service of the National Oceanic and Atmospheric Administration. Seattle, Washington.

MEC Analytical Systems, Inc. (MEC). 1996. Marine sediment bioassays. Prepared for King County Department of Natural Resources. Prepared by MEC Analytical Systems, Inc., Carlsbad, California.

Metro Environmental Laboratory. 1994. Quality Assurance Review for Duwamish/Diagonal Sediment Cleanup Study. Prepared for the Elliot Bay Duwamish Restoration Program. December 23, 1994

Municipality of Metropolitan Seattle (METRO). 1987. Quality of Local Lakes and Streams: 1985-1986 Status Report. Metro Water Pollution Control Department. Seattle, Washington.

Municipality of Metropolitan Seattle (METRO). 1988. Final 1988 Combined Sewer Overflow Plan, Plan for Secondary Treatment Facilities and Combined Sewer Overflow Control. Prepared for the Elliott Bay/Duwamish Restoration Program Panel. Seattle, Washington.

Michelsen, Teresa C. 1992. Organic Carbon Normalization of Total Organic Carbon in Soil/Sediment Data (Technical Information Memorandum). Washington Department of Ecology, Sediment Management Unit. Olympia, Washington. December 1992.

Michelsen, Teresa C. 1995. Letter from Teresa Michelsen, Washington Department of Ecology, to Pat Romberg, Metro. June 28, 1995.

National Oceanic and Atmospheric Administration (NOAA). 1989. A Method for Analyses of Butyltin Species and Measurement of Butyltins in Sediments and English Sole Livers from Puget Sound. National Oceanic and Atmospheric Administration. Marine Environmental Research, Vol. 27, 1989.

Pacific International Engineering, PLLC (PIE). 1998. Bottom Scour by Outfall Discharge, Foss Waterway Outfall - Sediment Scour. Appendix G of the Round 3 Data Evaluation and Pre-Design Evaluation Report, Thea Foss and Wheeler-Osgood Waterways, Tacoma Washington prepared by the City of Tacoma.

Palermo, M.R., el al., 1998. Guidance for Subaqueous Dredged Material Capping. Technical Report DOER-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg Mississippi.

Parametrix, Inc. 1980. Port of Seattle Terminal 107 Fisheries Study. Prepared for the Port of Seattle. Seattle, Washington.

Parametrix, Inc. 1982. 1980 Juvenile Salmonid Study. Prepared for the Port of Seattle. Seattle, Washington.

Port of Seattle, 2000. East Waterway Channel Deepening Project - Alternatives Development. Prepared the Port of Seattle and the US Army Corps of Engineers. March 26, 2000.

Prych, E.A., W.L. Haushild, and J.D. Stoner, 1976. Numerical Model of the Salt-Wedge Reach of the Duwamish River Estuary, King County, Washington, U.S. Geological Survey Prof. Paper 990.

Puget Sound Estuary Program (PSEP). 1988 Update and Evaluation of Puget Sound AET -- Sediment Quality Values Refinement: Vol. 1 and Vol. 1 Data Appendices. Prepared for the U.S. Environmental Protection Agency, Region 10. Seattle, Washington.

Puget Sound Estuary Program (PSEP). 1991. Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediment (Interim Final). Prepared for the U.S. Environmental Protection Agency, Region 10. Seattle, Washington.

Puget Sound Estuary Program (PSEP). 1995. Recommended Guidelines for Conducting Laboratory Bioassays on Puget Sound Sediments. Final Report. Prepared for the U.S. Environmental Protection Agency, Region 10. Seattle, Washington. Washington Department of Ecology, Olympia, Washington.

PTI Environmental Services. 1993. Development of an Aquatic Management Plan for Elliott Bay and the Duwamish Estuary: A Study. Prepared for Puget Sound Water Quality Authority, Olympia, Washington. Bellevue, Washington

Santos, J. F., and J. D. Stoner. 1972. Physical, Chemical, and Biological Aspects of the Duwamish River Estuary, King County, Washington 1963-1967 (Geological Survey Water-Supply Paper 1873-C). Washington, D.C.

Sumeri, A. 1996. "Dredged Material is Not Spoil: A Report on the Use of Dredged Material in Puget Sound to Isolate Contaminated Sediments." Proceedings of the Western Dredging Association 17th Technical Conference and 29th Annual Texas A&M Dredging Seminar, June 1996.

Swarner, B. King County Department of Natural Resources, Personal Communication, September 1999.

Sweet, Edwards & Associates and Harper-Owes. 1985. Duwamish Groundwater Studies. Prepared for Metro. Seattle, Washington.

Tanner, C. D. 1991. Potential Intertidal Habitat Restoration Sites in the Duwamish Estuary. Prepared for the Port of Seattle Engineering Department and The U.S. Environmental Protection Agency Environmental Evaluations Branch. Seattle, Washington.

Tetra Tech, Inc. 1988. Elliott Bay Action Program: Evaluation of Potential Contaminant Sources. Prepared for the U.S. Environmental Protection Agency, Seattle. Bellevue, WA: Tetra Tech, Inc.

Trustees. 2000. Commencement Bay Natural Resource Trustees Sediment Cleanup Goals for Active Natural Resource Restoration Projects. Downloaded from http://www.darcnw.noaa.gov/download.htm#gen on June 16, 2000.

Unger, M. A., W. G. Macintyre, J. Reaves, and R. J. Huggett. 1986. GC Determination of Butyltins in Natural Waters by Flame Photometric Detection of Hexyl Derivatives with Mass Spectrometric Confirmation. Chemosphere, Vol. 15, pp. 461-470. 1986

U.S. Army Corps of Engineers (USACE). 1978. Aquatic Disposal Field Investigations Duwamish Waterway Disposal Site, Puget Sound, Washington; Appendix E: Release and Distribution of Polychlorinated Biphenyls induced by Open-water Dredge Disposal Activities, Technical Report D-77-24. Washington, D.C.: Office, Chief of Engineers, U.S. Army, January 1978. Prepared by Pavlou et al.

U.S. Army Corps of Engineers (USACE). 1981. Duwamish Waterways Navigational Improvement Study: Analysis of Impacts on Water Quality and Salt Wedge Characteristics.

Varanasi, U., E. Casillas, M. R. Arkoosh, T. Hom, D. A. Misitaano, D. W. Brown, S. L. Chan, T. K., Collier, B. B. McCain, and J. E. Stein. 1993. Contaminant Exposure and Associated Biological Effects in Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) From Urban and Nonurban Estuaries of Puget Sound. Prepared by the National Marine Fisheries Service. Seattle, Washington.

Warner, Eric J. and Robert L. Fritz, 1995. The Distribution and Growth of Green River Chinook Salmon (*Oncorhynchus tshawytscha*) and Chum Salmon (*Oncorhynchus keta*) Outmigrants in the Duwamish Estuary as a Function of Water Quality and Substrate, Muckleshoot Indian Tribe, Fisheries Department, Water Resources Division, 39015 172 Avenue SE, Auburn, WA August 1995.

Washington State Department of Ecology (Ecology). 1991. Sediment Cleanup Standards User Manual, First Edition. Washington Department of Ecology, Sediment Management Unit. Olympia, Washington. December 1991.

Washington State Department of Ecology (Ecology). 1995a. Sediment Management Standards, Chapter 173-204. Olympia, Washington. Amended December 1995.

Washington State Department of Ecology (Ecology). 1995b. Guidance for Remediation of Petroleum Contaminated Soils (Revised Edition). Washington Department of Ecology, Toxics Cleanup Program. Olympia, Washington. November 1995. 91-30.

Washington State Department of Ecology (Ecology). 1996. Sediment Management Standards Marine Bioassays. Task II: Recommended Quality Assurance and Quality Control Deliverables. Publication No. 96-314. March 1996.

Washington State Department of Health. 1995. Tier I Report - Development of Sediment Quality Criteria for the Protection of Human Health. June 1995.

Washington State Department of Fisheries, A Catalog of Washington Streams and Salmon Utilization, Volume 1, Puget Sound Region, November 1975.

Weston, Roy F. Inc. 1993. Remedial Investigation Report, Harbor Island: Part 2-Sediment. Prepared for the U.S. Environmental Protection Agency, Region 10. Seattle, Washington.

Weston, Roy F. Inc. 1999. Site Inspection Report, Lower Duwamish River (RK 2.5 to 11.5), Seattle, Washington. Prepared for the U.S. Environmental Protection Agency, Region 10. Seattle, Washington. April 1999.